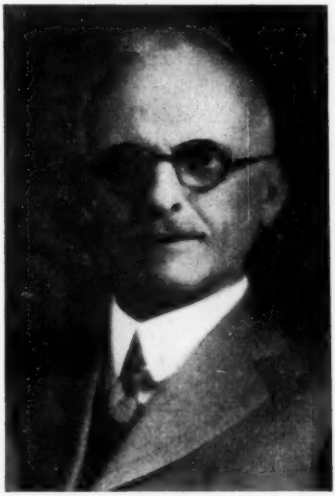
Popular Astronomy

Vol. L, No. 4 APRIL, 1942 Whole No. 494

Heber Doust Curtis
1872-1942

By DEAN B. McLAUGHLIN

Professor Heber Doust Curtis, head of the department of astronomy and Director of Observatories of the University of Michigan, died at the Observatory residence in Ann Arbor, January 9, 1942, after an illness of a few days. He is survived by his wife, Mary D. Curtis, to whom he was married in 1895; by a daughter, Mrs. A. J. Walters; by three sons, Rowen D., Alan B., and Baldwin R.; and by five grandsons.



HEBER DOUST CURTIS

Dr. Curtis was born at Muskegon, Michigan, June 27, 1872. His mother was of English parentage, and his father a tenth generation American, alumnus of the University of Michigan and veteran of the Union army. Young Heber wished to enter Annapolis, but he fell short of the requirement as to height. His father wanted him to study for the ministry, but he himself preferred engineering. Between these conflicting desires he struck a compromise in the study of Latin, Greek,

Hebrew, and Sanskrit. He completed his undergraduate work at the University of Michigan in three years, graduating in 1892. He carried on one year of post-graduate study and received the degree of Master of Arts in 1893. It has been a surprise to many that he never set foot inside the University observatory as a student. His interest in astronomy was aroused at a later date, when he had to teach mathematics "one jump ahead of the class" as he expressed it.

His first position was as teacher in the Detroit High School for the first year after he left the University. From 1894 to 1897 he was Professor of Latin at Napa College, California. Almost by chance he was diverted into the field of his life work, and during the next three years he was Professor of Mathematics and Astronomy in the College of the Pacific at San Jose. There he had a small but good Clark refractor, and during the summers he served as volunteer assistant at the Lick Observatory. It was probably the encouragement he received from Edward S. Holden, then Director of the Lick Observatory, which led Curtis to make the final decision on a career in astronomy.

Work towards the doctorate was next on the program. He applied for and received the Vanderbilt Fellowship in Astronomy at the University of Virginia. The date was particularly opportune, for he was able to make the eastward journey in time to observe the total solar eclipse of May, 1900, at Thomaston, Georgia, with the Lick Observatory party. Campbell and Perrine were strongly impressed by his handiness in mounting and adjusting instruments, and this was a factor in assuring him of a place at Lick Observatory as soon as he had obtained the Ph.D. degree.

The Vanderbilt Fellowship carried a stipend of $350 per year. How he and Mrs. Curtis and two children lived on that amount for two years is a problem to tax the imagination. At the University of Virginia he studied under Professor Ormond Stone and received the degree of Doctor of Philosophy in 1902. His dissertation was: "Definitive determination of the orbit of Comet 1898 I." His regular studies and his thesis did not occupy all of his attention, however, for he made a number of observations of Eros during its close approach in 1900, and he accompanied the Naval Observatory eclipse expedition to Sumatra in 1901.

In 1902 he was appointed assistant in the Lick Observatory, with duties primarily in spectroscopy. Promotion to the rank of Assistant Astronomer came in 1904. At the end of 1905 he was sent to Santiago, Chile, to relieve Dr. W. H. Wright and take charge of the D. O. Mills Southern Station of the Lick Observatory. There he remained until July, 1909, when he returned to Mount Hamilton. He held the rank of Astronomer there until 1920, when he left to become Director of the Allegheny Observatory. In 1930 he succeeded the late Dr. Ralph H. Curtiss as Director of Observatories at the University of Michigan,

which position he occupied until his death. He was scheduled to retire on June 30, 1942.

The latter period of his work at Lick Observatory suffered an interruption during the first World War, when he taught navigation at San Diego, and later he worked in the optical section of the Bureau of Standards at Washington.

Dr. Curtis' professional bibliography includes 135 titles, exclusive of reviews. He made contributions in the fields of comet orbits, stellar spectroscopy, orbits of spectroscopic binaries, photographic observations of comets, solar eclipses, studies of nebulae, theories of the universe, and instrument construction.

In the early days at Lick Observatory he worked chiefly on the great radial velocity program with the Mills spectrograph and the 36-inch refractor. Referring to the coöperative nature of that work, he has stated: "We were all 'hewers of wood and drawers of water'—and liked it; it all seemed to be a necessary part of the big observatory's life, and I think that none of us ever had the slightest feeling that it was routine." During that time, however, he also carried on independent researches and made important contributions off the beaten track. One result of the radial velocity program was the discovery of a number of spectroscopic binaries, and he computed the orbits of several of them. The most interesting was Castor, both of whose visual components were found to have variable velocity. Work in this same field was continued while he was in charge of the D. O. Mills Southern Station. Numerous mechanical improvements about the telescope also dated from the period of his residence there.

During his sojourn at Santiago, Comet Morehouse (1908c) appeared, and Curtis secured an excellent series of photographs of it. Soon after returning to Lick Observatory he concentrated on Halley's comet with the Crossley reflector, and the fine set of photographs he obtained has yielded much important information.

Solar eclipses were his especial joy. He took part in eleven expeditions, not quite realizing his ambition to make it an even dozen. The first two have been mentioned already. There followed three Lick Observatory expeditions: to Labrador in 1905; to Russia in 1914; and to Goldendale, Washington, in 1918. After he went to Allegheny Observatory he accompanied four expeditions from the Sproul Observatory: to Mexico in 1923; New Haven in 1925; and to Sumatra in 1926 and 1929. In 1930 he conducted his own expedition to Nevada to observe the very brief eclipse which was annular over most of its path. As Director at Michigan he organized his last eclipse expedition to Fryeburg, Maine, in 1932. Illness compelled him to abandon at the last minute his plans to accompany the expedition to Canton Island in 1937.

At the earlier eclipses he took part in the general programs of photography and search for intra-mercurial planets. At the later ones he

made repeated attempts to obtain interference fringes in the image of the green coronal line. The infra-red coronal and flash spectra which he secured in 1925 gave the first such records of an important region of the spectrum. Whether as a member of an expedition or as its leader, there was never a person in the party more active than he. Both in preparation at home and in mounting and adjusting instruments at the eclipse camp, he found the most satisfying outlet for his mechanical ability and his boundless energy. He enjoyed too the travel to distant places and the opportunities which these trips afforded to meet people of other lands. I recall his fluency in the Malay language, which was an indispensible accomplishment for at least one member of any eclipse party in Sumatra, and he more than made up for the linguistic deficiencies of other members of the expedition.

His greatest individual research contribution was made during the period at Lick Observatory after his return from Chile. As astronomer in charge of the Crossley reflector, he undertook studies of the nebulae. The fine set of photographs and drawings of planetary nebulae in Volume 13 of the *Lick Observatory Publications* is a classic. Counts of faint extra-galactic nebulae on the Crossley plates led him to estimate the number accessible to that instrument as approximately a million,—at that time a staggering figure, though it has since proven to be conservative. Others of his observations gave strong support to the belief in dark nebulae, as opposed to "holes in the sky"; in particular his study of the dark "lanes" in spiral nebulae crystallized in his mind the explanation of the lack of spirals in the Milky Way as caused by a similar band of obscuring material about our own system. He discovered several novae in spiral nebulae, and from their apparent brightnesses he gave rough estimates of distance which were of the order of magnitude that has since been established by the use of Cepheid variables and other statistical methods. In subsequent papers he marshalled, in clearer fashion than ever before, the evidence which supported the "island universe" theory as against the view that our stellar system is unique.

During the same time, however, there was a growing tendency among astronomers generally to regard the spirals as small nearby objects, and to reject the island universe theory. This was brought about mainly through the accumulation of evidence that our system was much larger than had been previously supposed, but the lack of recognition of absorption of light by interstellar matter led to a gross overestimate of the dimensions of our own galaxy. As Curtis remarked once, in my hearing, there was a time about 1923 when he was practically an "Irish majority" in his adherence to the island universe theory. The power of the Crossley was not quite equal to the task of producing conclusive proof. When the crucial evidence was obtained by Hubble with the 100-inch reflector, the change in our views of the universe was sudden and dramatic. Once and for all, there was established the truth of the

concept of the plurality of galaxies which Curtis had championed.

Some years later, while at Michigan, he prepared the chapter on the nebulae for the *Handbuch der Astrophysik*.

At the Allegheny Observatory, Dr. Curtis built up the machine shop and designed and constructed a number of instruments. One of the first jobs he undertook was to grind the periodic error out of the driving worm of the 30-inch refractor. He concentrated also on solar eclipse work, and took part in five expeditions during those ten years. Although he did not do any of the actual measurement of stellar parallaxes, he regularly took his turn at the 30-inch refractor in securing the parallax photographs.

When he came to Michigan in 1930, it was expected that the University would soon have a new observatory, and it was to be his task to plan and equip it. Soon after he became established in Ann Arbor he plunged into the work of designing an 85-inch reflector. The plans were completed, but the reduction of funds incident to the depression made necessary the indefinite postponement of construction. However, against the day when the telescope could be built, he ordered a disk of pyrex. The first one proved defective. When the time came for a second pouring, the Corning Glass Works offered to increase the dimensions at a small additional cost, and Curtis readily agreed. The second pouring was successful, and the 97-inch disk is now stored behind the observatory in Ann Arbor. The mounting will need to be redesigned to fit the larger mirror, but the general plan and many original features of design may go far to simplify the problem for the one who makes the final plans.

During the eleven years at Michigan much of his time was consumed in administrative work, and he took part in the teaching program of the department. He regularly taught a section of that half of the course in descriptive astronomy which dealt with the stellar system; occasionally he gave a seminar course in cosmogony, and in one semester each year he taught navigation. He was rather proud of his speed and dexterity with a sextant, an accomplishment which can be vouched for by anyone who has accompanied him on an eclipse expedition.

For several years, so long as his health permitted, he regularly took part in the spectrographic observing program with the 37-inch reflector. It was with him a matter of "astronomical conscience" that he should take some of the spectrograms, though he never undertook a research problem based on them. He always insisted on observing in the second half of the night; the sole exception to this rule occurred on that first hectic evening after the appearance of Nova Herculis. Even when he was not observing, he kept partially astronomical hours. Regularly the observer on "second half" would hear him drive out at about 4:00 A.M. for his morning coffee at "The Greek's," and the coming of dawn would find him at work in his office. During the last few years recurrent

spells of illness caused him to decide at last: "My days of night work are over."

To the observatory staff he was known as "The Boss," but the nickname carried no suggestion of domination over others. He preferred a policy of leaving people severely alone, so far as possible, to carry on their researches or teaching according to their own ideas, but he was always ready with advice and suggestions when they were expected of him. Under his administration a considerable volume of scientific papers came from the observatory, both in its *Publications* and in the scientific journals. He was particularly adept at editing papers for publication, and though I sometimes wondered whether the final result would be more than an abstract, the published version of the paper was always conspicuously improved as a result of his scrutiny. He apparently had two principal rules for editing: (1) be as brief as possible, even telegraphically so; (2) never make a thing complicated if it can be made simple; words should convey ideas,—not obscure them.

The period of his directorship was particularly marked by the growth of the McMath-Hulbert Observatory at Lake Angelus. It was in large measure Dr. Curtis' interest in and encouragement of that program of work that made possible the rapid development and great productivity of that part of the institution. That intricate equipment for mechanized attack on solar problems is a fitting monument to one who derived so much pleasure from the construction of fine instruments.

This account cannot do justice to his versatility. His outlook was more characteristic of an earlier generation before the sciences had become so highly specialized. His mind had great possibilities in many directions. He was literary beyond most scientists, and his breadth and catholicity of interests led him to cross the boundaries of his own subject. In writing and speaking he seemed to achieve without effort an ease and grace of expression which not all literary people possess, and he was an unexcelled popular lecturer. He was not overwhelmed by astronomical magnitudes and by man's relatively insignificant place in the universe. Instead, he insisted, man has a mind that can comprehend it; even though the universe is infinite, man's mind also is infinite in its possibilities. He loved teaching but he abhorred mere "rehashing" of the textbook; he felt that a teacher must give something more, of his own. This independence was perhaps a part of his reason for refusing attractive offers to write a text in descriptive astronomy.

Dr. Curtis was always interested in the people about him, and he was admirably suited to life on Mount Hamilton, where it was sometimes necessary for neighbors to "borrow everything needful, up to and including the other's roast of beef to feed the unexpected guest." He took a keen interest in the good of the community, and he engaged in a number of non-scientific projects, including construction of the tennis court and the golf course. He was a good sport and good companion, and he

especially enjoyed whist, and later bridge, in the atrocious winter evenings on the mountain, when the dummy would keep a weather eye out for breaks in the clouds.

His car was one of the first on the mountain, and it was a veritable community bus, filled to capacity on every trip to San Jose. To the end of his life he found genuine relaxation in driving at what some would call an incautious pace, going, as he said, "anywhere,—it doesn't much matter." It was a saying among members of the Michigan staff that he slowed down to sixty miles per hour for railroad crossings.

This last was just another symptom of his energy and love of action, which was reflected in his admiration of men of action and men who were "doing things." In keeping with this was his love of the works of Kipling, whose poems he quoted profusely and accurately. Many times I recall coming to a class following his in the same room, to find a stanza or two of Kipling on the blackboard.

He was a member of the First Methodist Church of Ann Arbor, and served for several years as president of the Wesleyan Guild, and in charge of the Henry Martin Loud Lectures. He was not a sectarian, was impatient of "churchianity," and sought out distinguished men in any church,—Catholic, Jewish, Unitarian or Episcopalian. He was keenly interested in philosophy and in the relations between science and religion, a subject on which he lectured on several occasions. He never uttered a creed, but had a deep and real faith.

Dr. Curtis was a member of the National Academy of Sciences and of the American Philosophical Society, and he always made a point of attending the annual meetings of those bodies. In the American Association for the Advancement of Science he served as Chairman of Section D; in the American Astronomical Society he had held the offices of Councilor and of Vice-President. He was a Foreign Associate of the Royal Astronomical Society, and a member of the Commission on Solar Eclipses in the International Astronomical Union. Locally, he was a member of the Philosophical Club, the Catholepistemiad, the Research Club, and Witenagamote in Detroit. All these groups will sorely miss his friendly personality and keen humor. With his passing, the University of Michigan and the world of science have lost a scholar of the first rank, and one of their best-loved members.

University of Michigan, Ann Arbor.

Solar Terrestrial Relationships*

By HARLAN T. STETSON

The problem of solar-terrestrial relationships is one not only of astronomical significance but very much of geophysical significance as well. There has been great advance in our knowledge in recent years of the state of ionization of the earth's upper atmosphere through the science of radio-wave communication. The hypothesis of an ionosphere surrounding the earth as a medium for refraction and reflection of electromagnetic waves has made possible the application of physics to a problem directly involving solar radiation as the probable source of the ionization of the upper atmosphere.

Communication conditions depend not only upon the amount, but also upon the character of the ionizing radiation. Radio technique now provides physical methods for the measurement and study of otherwise inaccessible regions of the atmosphere, and has already led to new and important conclusions in the whole matter of solar-terrestrial relationships.

Heretofore most attempts in studying recurring solar and terrestrial phenomena and their relationships for the most part have rested upon the rather unsatisfactory method of comparing similarities between curves of more or less concomitant phenomena. The fact that radio engineering has now supplied a satisfactory mechanism for tracing atmospheric effects to solar phenomena offers a physical basis for a study of interrelationships not previously possible.

Every student of astronomy acquainted with the textbooks of even a generation ago was readily made aware of the close correspondence between changes in the earth's magnetic field and periodic changes in the sun marked by the occurrence of sunspots. This relationship was incontestably established as perhaps the outstanding example of terrestrial phenomena that may be traced to solar origin by the method of comparison of graphs.

It was not, however, until the advent of the radio with the hypothesis of an ionosphere as a medium for the propagation of radio waves that any satisfactory mechanism connecting sunspots with geomagnetic activity was found. The circulation of ions and electrons in the upper atmosphere is the equivalent of an electric current flowing about the earth. Any change in the intensity in this atmospheric electric current due to changes in the ionosphere will obviously induce magnetic effects that account for the change in magnetic variation found to accompany the solar cycle.

A cross-section of the earth's atmosphere, Fig. 1, made possible from the study of radio-wave propagation reveals two or three distinct layers

*Presented at the Dallas Meeting of the A.A.A.S., Section D.

of ionization. The uppermost of these, the so-called F or Appleton layer is the one responsible for turning back to earth the radio waves of high frequency, or of short wave-length. The altitude of this layer has both a diurnal and seasonal variation, but may be generally stated as at

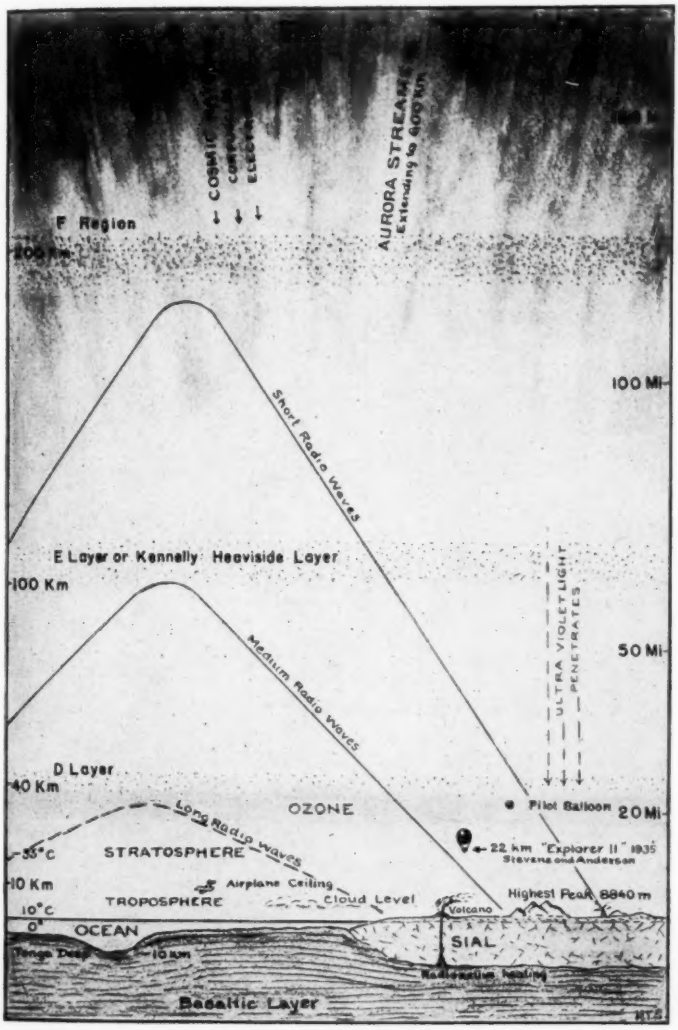


FIGURE 1
CROSS-SECTION OF EARTH'S ATMOSPHERE

about the 200 km. level.

At about 100 km. there is again an ionic concentration producing the E layer, or that commonly known as the Kennelly-Heaviside layer. It is this layer that is responsible for the reflection of radio waves of medium frequencies commonly used in broadcasting commercial programs. The behavior of very long waves suggests the existence of still another ionization level at an altitude of about 40 km. sometimes referred to as the D layer.

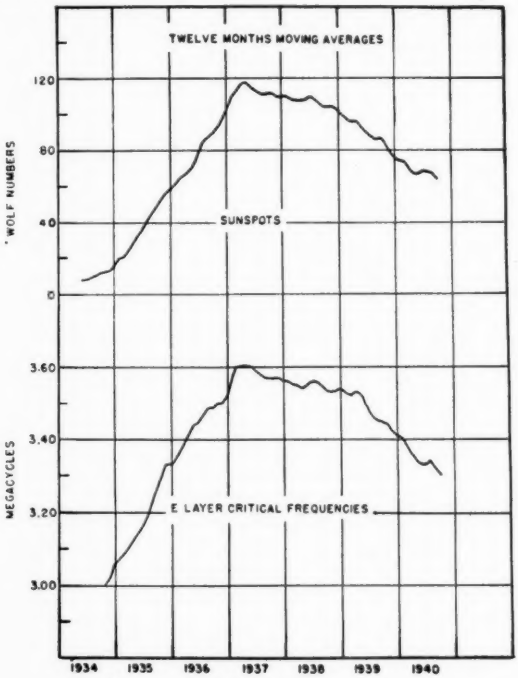


FIGURE 2

By sending waves of known frequency to the top of the atmosphere, and varying the frequencies throughout the radio spectrum it is possible to determine the exact wave-length at which the electro-magnetic waves are turned back from each of these successive layers. By observing the elapsed time interval between the up-going wave and the reception of its echo, the height of the reflecting level is determined. The highest frequency at which reflection occurs is commonly called the critical frequency. This critical frequency is found to vary throughout the day and the year and furthermore with the eleven year sunspot cycle. In Fig. 2 is represented the marked change in critical frequencies of the

E layer during the recent sunspot cycle from 1934-40. A comparison of this curve with that of the curve of sunspot numbers shows how closely conditions in the ionosphere at the E layer depend upon solar activity as indicated by the Wolf sunspot numbers. Knowledge of the critical frequencies makes it possible to calculate the electron density at each of the reflecting layers.

To account for the high state of ionization resulting is a problem not yet completely solved. Since the changes in ionization so definitely follow the zenith angle of the sun, it is obvious that solar radiation, presumably at the ultra-violet end of the spectrum, must be the agent chiefly responsible for the degree of ionization encountered. Here we run into difficulties for calculations seem to demand an energy in solar radiation two or three times the amount permissible on the assumption that the sun radiates as a black body at a surface temperature of 6,000° K. Students of radio-wave phenomena postulate, therefore, that the energy in the solar spectrum outside the earth's atmosphere in the extreme ultra-violet region must exceed several fold that to be expected on the basis of black body distribution. Furthermore, from measurements in this country and abroad, it would appear that the change in the state of atmospheric ionization that must take place between sunspot maxima and sunspot minima is of the order of from 50-60 percent. Appleton points out that this variation necessitates a corresponding energy change in the extreme ultra-violet of the solar spectrum of from 120-150 percent.[1]

More recently, Preston[2] in endeavoring to account for the high states of ionization accompanying radio fadeouts has found it necessary to postulate radiation from the sun of such high frequencies as to correspond to wave-lengths of the order of 2 Ångstroms or less. Such radiation would therefore be of the nature of x-rays of exceedingly high energy, and presumably difficult to account for on present astrophysical grounds.

In addition to the method of determining the state of the ionized layers through the determination of critical frequencies by the echo method, there are other independent means for determining the changes in the state of the ionization of the earth's upper atmosphere. One of these, although not simple in its interpretation, is that of the measurement of the field strength of radio waves from a known source over a given distance. Such measurements reflect most markedly not only both the diurnal and seasonal periods but the period of the cycle of solar activity as well. With the establishment of a special laboratory for cosmic terrestrial research at Needham, Massachusetts, in connection with the Massachusetts Institute of Technology, continuous records have been made of field strength measurements of both medium and short wave-lengths emitted from transmitters so distant as to eliminate the ordinary ground wave reception.

Every radio listener who has tuned in on distant broadcasting stations

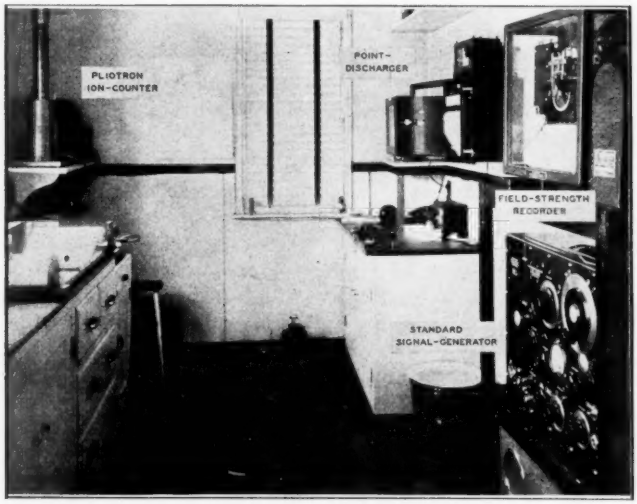


FIGURE 3

CORNER OF A RECORDER-ROOM, SUBURBAN LABORATORY FOR COSMIC-TERRESTRIAL RESEARCH, NEEDHAM, MASSACHUSETTS.

knows that long-distance reception is in general stronger in winter than

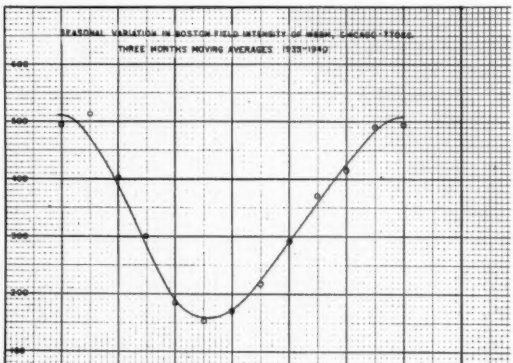


FIGURE 4

in summer and that night reception is better than day reception at broadcast frequencies. A curve showing the seasonal variation in field

strengths of a Chicago station observed in the vicinity of Boston is shown in Fig. 4. Here the nightly field intensities observed in winter are more than four-fold those observed during the summer months of June and July. It is obvious that in the study of changes in the ionosphere with the eleven year solar cycle allowance has to be made for this known seasonal variation as well as for the diurnal variation incident to the transition from twilight to darkness.

By the comparison of observations of critical frequencies by the echo method with field strengths measured simultaneously at this laboratory, it has been possible over a limited period to approximate values of changes in field strengths with corresponding values in ionic concentration at the appropriate levels. From such deductions, we are led to believe that a change in measured field strengths of 40 percent may ensue from a change in ionic concentration in the upper layers of the order of but a very few percent. It is suggested, therefore, that field strength measurements afford a means of examining a fine structure in ionic states as compared to the more general determinations from the critical frequency methods. As an analogy we might say that the method of study of field strengths bears somewhat the relation to the study of critical frequencies as do the methods of interferometry to those of spectroscopy.

In dealing with the question of the ionization of the upper atmosphere by solar radiation, two distinct mechanisms appear to be necessary at the moment for an explanation of observed phenomena:[3] (1) The so-called W radiation characterized as wave phenomena into which the ultra-violet theory of ionization is most easily fitted; (2) that commonly designated as P radiation which presupposes particles emitted from the sun from disturbed centers and which travel at relatively slow velocities of one to two thousand kilometers per second.

In the first category must be included not only the general ultra-violet radiation presumably responsible for the ionization of the F and E layers of the ionsphere, but also certain bursts of intense ultra-violet radiation accompanying the outbreak of intensely brilliant flocculi. Such outbreaks have been observed on the sun's surface concomitant with extensive fadeouts of radio waves. Fadeouts of this nature are confined to the daylight half of the earth's atmosphere. These fadeouts may persist for a period of from a few minutes to an hour or more and are invariably accompanied by geomagnetic disturbances. These radio disturbances fall into the category of ionospheric storms.

The hypothesis of P radiation originated in an endeavor to explain more prolonged ionospheric and geomagnetic disturbances entailing both day and night communication that may be of several days duration. Auroral displays may frequently accompany the more pronounced disturbed days of this character. In fact, auroral phenomena probably support more strongly the hypothesis of P radiation than perhaps any other observed phenomena. The extensive mathematical analysis of

Störmer's that has made possible the delineation of auroral forms as tracks of ionization in the upper atmosphere where charged particles enter the polar regions has gone far to substantiate the reality of the hypothesis of P radiation.

An analysis at the laboratory for Cosmic Terrestrial Research of the occurrences of auroral phenomena as related to solar activity on the one hand, and studies of radio field strength determinations on the other, leads to the conclusion that a period of from 24 to 36 hours elapses between the time of maximum activity near the solar meridian and the

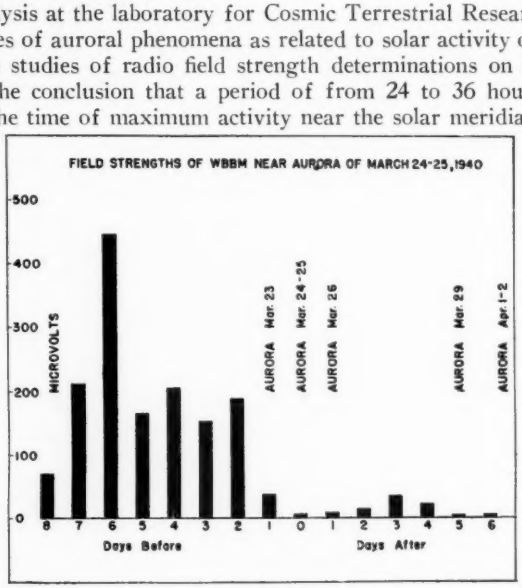


FIGURE 5

date of auroral occurrence with the subsequent disturbances to the F and the E layers. This is illustrated specifically in the case of the aurora of March 24-25, 1940, (Fig. 5) and the more recent brilliant display of September 18, 1941, (Fig 6).

An analysis of ten years' observations[4] of auroral and radio phenomena represents even more satisfactorily the relation between the period of maximum solar activity, auroral occurrences, and disturbances in the F and E layers (Fig. 6). The delay of one day from maximum solar activity to the occurrence of the aurora suggests a velocity of the particles in the P radiation of the order of 1000 km. per second, quite consistent with the theory advanced by Grotrian[5] of particle emission. The delay of from 24-36 hours between the auroral occurrence and maximum disturbances in the E layer suggests a prolonged interval in the penetration of the ionizing particles in the earth's atmosphere or that the ratio between ionization and recombination at the 100 km. level attains its maximum in from 24-36 hours after the particles responsible for the ionization process have reached the outer limits of the earth's atmosphere.

The fact that geomagnetic disturbances occur promptly with the disturbances in the F layer suggests that the region of the ionosphere most nearly associated with magnetic storms lies near the 200 km. level.

The delayed recovery in ionospheric communication at all frequencies indicates the universal character of the induced disturbances. The longer period of recovery required for E layer communications compared with F layer communications is significant of the greater damage to broadcast frequency transmission.

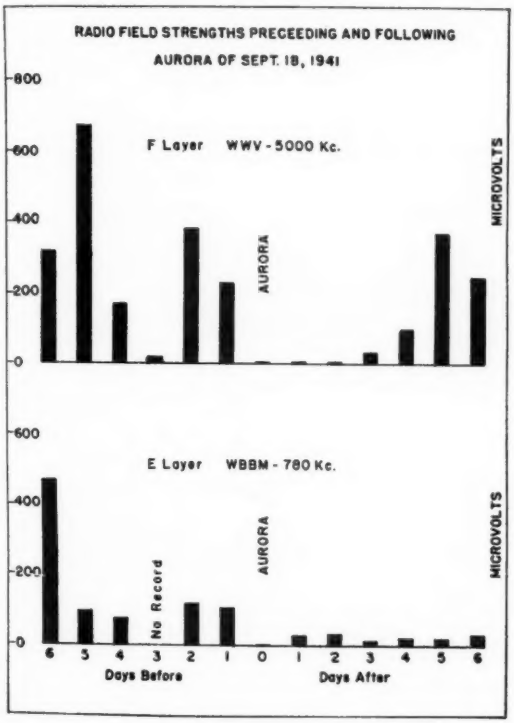


FIGURE 6

The above discussion indicates the intimate relationship between solar changes and geophysical phenomena and even suggests that the newer methods of radio technique may prove an important instrument for studying changes in the character of the solar radiation itself.

The importance of the possible bearing of upper atmospheric phenomena upon conditions in the troposphere is just now beginning to receive the attention of the newer school meteorologists. It appears not improbable that further investigation may yield important information

concerning the general circulation of the lower atmosphere as in some way dependent upon the state of the upper atmospheric layers. It is not inconceivable that small variations in the amount of solar radiation may ultimately have a more profound effect upon the circulation of the lower air with accompanying changes in temperature and precipitation than would have been expected on the grounds of the small variations in solar radiation customarily observed.

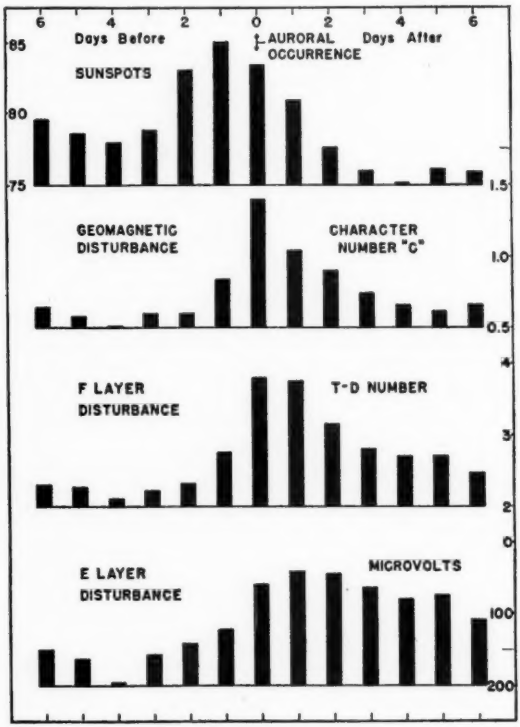


FIGURE 7

This suggests the importance of more extended measurements in the ultra-violet region of the solar spectrum both by means of radiosondes reaching to the lower stratosphere and supplementary measurements at the earth's surface. Such ultra-violet measurements over extended areas made daily throughout the sunspot cycle, might be expected to yield important information relative to the changes in solar radiation of short wave-lengths possibly related to changes observed by radio technique. However, even at levels attainable by sounding balloons, the absorption would still be great in the region of the extreme ultra-violet,

and one might still have to infer variations of extremely high frequency at the E and F layer levels not detectable by other means than radio engineering methods.

The radio method of approach to tne problems of solar meteorological relationships may well prove in the end to be more satisfactory than the intercomparison of recurrent weather phenomena with sunspot numbers, or any other single criterion of solar activity, such as has so often been employed with disappointing results.

Existing correlations of sunspot numbers with tree growth, lake levels, and the like that have appeared to be reasonably well substantiated over varied lengths of time will probably in the end appear incidental to some more fundamental relationships in geo-atmospheric phenomena yet to be ascertained.

The close correspondence of solar activity with upper atmospheric ionization as determined from critical frequencies has been remarkably exhibited throughout the last solar cycle. This leaves little to be desired as an illustration of the dependence of upper atmospheric ionization on solar radiation throughout the sunspot cycle. It is here of interest to remark that the anticipated behavior pattern of solar activity in the present cycle has already demonstrated its usefulness in warranting predictions of communication conditions well in advance, predictions that have in most instances been remarkably verified.

References

[1] Appleton, E. V., "The Variation of Solar Ultra-Violet Radiation during the Sunspot Cycle," *Philosophical Magazine*, Ser. 7, **27**, 144-148, (1939).

[2] Preston, W. M., "The Origin of Radio Fade-Outs and the Absorption Coefficient of Gases for Light of Wave-Length 1215.7A," *Physical Review*, **57**, 887-894, (1940).

[3] Bartels, J., "Solar Radiation and Geomagnetism," *Terrestrial Magnetism and Atmospheric Electricity*, **45**, No. 3, 339-343, (1940).

[4] Stetson, H. T., "Auroras, Radio Field-Strengths, and Recent Solar Activity," *Terrestrial Magnetism and Atmospheric Electricity*, **45**, No. 1, 77-86, (1940).

[5] Grotrian, W., *Naturwiss.*, **27**, 555-563, 569-577, (1939).

Laboratory for Cosmic Terrestrial Research, Needham, Massachusetts.
January, 1942.

The Bands of Aristarchus

By ROBERT BARKER, F.R.A.S.

For many years the chief interest in Aristarchus seemed to center in the fact that this lunar formation marked the brightest area on the Moon's surface, and is easily detected when lit by earthshine on the unilluminated disc, when a proof of its intrinsic brightness appears. In the last decade, however, a new interest has dawned, many drawings have been made, many theories advanced, and much speculation arisen to account for the presence of very dark radial bands appearing under a higher sun upon the inner upper slope of the E. wall.

These bands appear to have been first noticed, as a novel feature, and advertised as such, by Goodacre in 1896. Webb, one of the finest observers astronomy has produced, omits any mention of these bands in his world famous "Celestial Objects," first published in 1859.

The earliest drawing of Aristarchus, of real interest and value that I can discover, is in a paper given by Professor John Phillips before the Royal Society in 1868. I have copied his sketch (see Fig. 1). He writes of "the interior surface, on which I have bestowed much attention, first with the 3-ft. mirror of Lord Rosse, next with my achromatic at York, and finally at Oxford with my 6-in. Cooke." The floor seems to reveal the *starting point* of 3 rather ragged bands, partly climbing the inner E. walls. It may be of interest to note that the Martian light area S. of Sabæus Sinus was called Phillips Island. This region later became known as Deucalionis Regio, when Schiaparelli introduced the classic nomenclature, which still prevails, to distinglish Martian features.

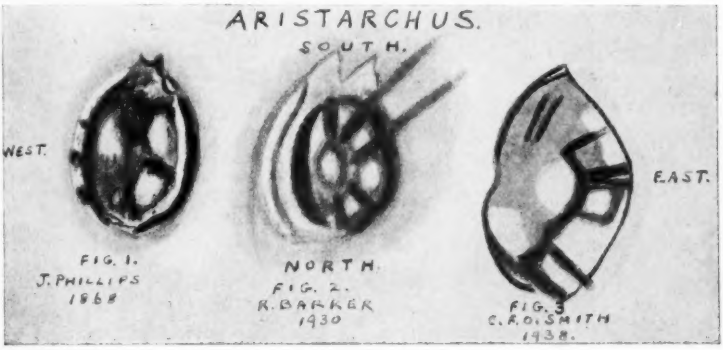
I have by me a large drawing of Aristarchus by Schmidt, when at Athens, dated 1866; but the floor and walls are innocent of any shading, neither is mention made in the text.

Neison in his great classic "Moon" (1876) has no reference to the bands, although Aristarchus is very fully described, and mention is made of considerable numbers of light streaks extending S. from Aristarchus.

In Elger's "Moon" (1895) there is a statement which leaves doubt as to whether or not this sharp observer saw the bands. "The brilliant inner slope of the E. wall" and "an oval area, nearly as large and fully as brilliant as the central mountain is seen on this inner slope. It is bordered on either side by bands of a duskier hue which probably represent shallow transverse valleys." In view of latter day developments the last sentence is puzzling.

Birt, a tireless searcher after evidences of lunar surface changes and an exhaustive writer on all lunar matters, also seems to be silent on this matter, which, curiously, escaped his critical eye. His finest work was accomplished between 1850 and 1875.

Fauth in his little book "The Moon," (undated) translated by Gore which preceded his recently published "Mond" (1936), though he deals with many lunar developments, and his own theories, makes no reference to the appearance or evolution of the bands, although he admits making lunar observations for 17 years. This is not a textbook, or guide to every lunar feature. W. H. Pickering's "Moon" (1904 is not a textbook, or authoritative guide of descriptive account of every lunar formation and feature. He chiefly deals with changes he has observed on the surface (in many cases actually photographed), together with the contributory causes. He assigns change in some cases, to vegetal growth, but omits any reference to the development of Aristarchus' bands. In the magnificent Paris lunar photographic atlas (Loewy and Puiseux 1904), Plate LVII shows Aristarchus under evening illumination, and a very faint streak can be traced down the outer slope of the E. wall towards Herodotus.



Serviss in his simply written and instructive treatise "The Moon" (1918), an excellent and most entertaining book, mentions a short ray starting out from Aristarchus in a S.E. direction. This ray is evidently not connected with the 2 dark extensions traversing the same area, for he writes further: "the *bright* ray connects Aristarchus with its neighbour Herodotus." He has much to say regarding Aristarchus, but no reference to the dark bands appears.

When in 1931 Goodacre published his "Moon," he incorporated the results of 60 years' study in this unapproachable book. He writes, "The brightness of the inner slope of the E. wall is reduced by 4 dark bands which radiate from the centre. These were independently noted by me, and are shown by Krieger in the drawing of Aristarchus in his Atlas. These curious dark rays do not appear to have been noticed by the earlier observers; 2 of them I have traced for a short distance over the crest toward Herodotus." Krieger's drawing was dated 1897. It is strange that Goodacre should have overlooked a drawing of Aristarchus in the 3rd

Lunar Memoir of the British Astronomical Association, by Dr. T. S. Sheldon, dated 1894. The sketch actually shows 2 bands, but Sheldon does not appear to have been impressed, and certainly failed to perceive any novelty, for he omits any reference in his accompanying text. It certainly appears that marked evolution, or growth, has taken place since. Goodacre noticed 5 bands later, and witnessed the extension of 2 bands over the crest. These increases and extensions were independently noted by myself, and it soon became apparent that the bands were no longer shadings, but black streaks easily seen in a small astronomical telescope.

The extensions, however, always show faintly over the darker surface traversed; sometimes not seen for several lunations, and always requiring good observational conditions to be seen at all. About 1930 I noticed that a faint penumbral shading now covered part of the bright spaces between the radial bands, linking the bands, and leaving a more or less circular bright gap between the bands. This shading was then very faint, and was glimpsed with difficulty. (See Fig. 2.)

In some lunations, when only 2 or 3 bands were presented, this newly found shading was limited to 1 or 2 spaces between the bands, or was not to be seen. I have never seen it except between the bands. Since the first recorded appearance, the depth of this shading has deepened, and has been photographed by the 100-inch reflector.

A recent observation by S. M. Green (Prescot, Lancs.) depicts 4 bands, the centre pair being very heavy and black. Green appends a pertinent note: "Just before Fall the streaks were scarcely visible. At 3rd quarter they were conspicuous even in very bad air, and the next night they were even more pronounced. Do they periodically vary in brightness? Vegetation?" Green's last word is significant.

C. F. O. Smith (Edinburgh), a very skilful lunarian, deals with the bands in an original manner in his paper before the B.A.A. last July. Smith suggests that many lunar markings which increased rapidly in brightness might be granular in texture. Walter Haas (New Waterford, Ohio) also holds this opinion, and in his "The Problem of Lunar Changes" (*Journal of R.A.S. Canada,* Sept. 1938) he writes "This granulation causes the area to vary in brightness, in intensity, with the ever-changing angle of incident light, and this produces the changes observed." Smith further suggests that if therefore a granulated patch can relatively grow brighter than a non-granulated one, it might be reasonably inferred that the areas covered by these bands *do not darken,* but only seem darker on account of the rapidly brightening contiguous area. Smith writes that there is evidence that the bands vary in position, sometimes appearing as radiating from the centre of the formation, at other times 2 or more may show an approach to parallelism, and 2 of the bands extend far beyond the E. margin.

Smith's interest was reawakened by 2 photographs of Aristarchus

(taken with the 100-inch) in *Publications of the Astronomical Society of the Pacific* (August, 1940) as there was much agreement between one of the photographs and his observations of February, 1938 (see Fig. 3). Notice a *forked* band (never before seen in Great Britain) and the *circular* penumbra N. of the forked band. All the bands exhibit irregularity, especially in the 100-inch photograph. Smith appears to hint at a prolongation of a band N, over the E. rampart, but he did not then see the extended S. pair of bands, although they were well known to him, neither do they appear in the photograph.

I cannot help thinking (and this is merely a personal opinion) that the granulation theory cannot apply to the 2 extended S. bands which are only seen at uncertain times. This theory, to carry weight, must apply equally to all or to none.

The States have only in recent years emulated the British in advanced lunar observations. Signs of awakening interest today, however, are manifest, and some highly meritorious work of Dr. S. R. B. Cooke (Rollo, Mo.) appears in the 9th Lunar Memoir (1936) of B.A.A. David P. Barcroft (Madera, Cal.), W. H. Haas, and Hugh M. Johnson (Des Moines, Iowa) have more recently entered this great observing field, Haas fast bidding to become one of the world's finest lunarians.

This is all to the good of observational astronomy, and when the world's troubles have eventually subsided, we in Britain cordially hope to join with your nation in advanced lunar research, so that our combined discoveries, theories, and deductions may forward the delightful study of selenography.

The writer has attempted to show in this paper a remarkable feature of evolutionary change on our satellite's face; a change which seems to have accelerated in rapid development during the last 11 years.

Lunar changes of a physical nature must be on a generous scale to be visible in the amateur's telescope. Every astronomer, with a telescope capable of bearing, with excellent definition, a magnification of $\times$ 300, can observe the present condition of Aristarchus' bands, and future evolution; and witness, maybe, the growth of lowly vegetation on another world, 240,000 miles distant.

DECEMBER, 1941.

Marvelous Voyages — III

Jules Verne's From the Earth to the Moon

By LAURENCE J. LAFLEUR

Jules Verne's story of a trip around the moon is perhaps his most pretentious tale; possibly even, considering the time when it was written, the most exhaustive treatment of the theme of extra-terrestrial transportation ever to be written. The author divided his story into two volumes, "From the Earth to the Moon" and "Around the Moon," and the contents are sufficiently interesting for us to follow his example and consider each volume separately.

In "From the Earth to the Moon" Verne relates how Barbicane, president of an American gun club formed in 1865, proposes that the club build a gun and shoot a projectile to the moon. He argues that a muzzle velocity of just over 36,000 feet per second (409 miles a minute) will be sufficient to do the trick, and that, as the resistance of gun barrels and the explosive power of gunpowder are practically limitless, it will be possible to achieve this initial velocity. The proposal is enthusiastically accepted by the club, and, indeed, by the nation and by the world at large.

Information on astronomical aspects of the proposal is requested of the Cambridge Observatory, which replies as follows. The distance of the moon at perigee is 218,657 miles, so much less than at apogee that advantage of the former should be taken. It is only necessary to send a projectile to the point at which lunar gravitation is equal to terrestrial, and it will fall the rest of the way. Consequently, the Observatory announces, the proposed velocity would be sufficient, and it would take the projectile to the neutral point in 83 hours and 20 minutes, whence it will fall to the moon in another 13 hours and 53 minutes. The most favorable time for the attempt is when the moon is simultaneously at its perigee and at the zenith, a rare occurrence, but one which is due to occur at midnight of December fourth of the following year, and which will not occur again for eighteen years and eleven days. The gun should be aimed at the zenith of some locality where the moon reaches the zenith, *i.e.*, between 0° and 28° of latitude, north or south. The shot should be fired at 10:47 P.M., December 1, which is the proper interval before the moon is at perigee. As the moon advances 13° 10′ 35″ each day, it will be, at the time of firing, 52° 42′ 20″ from the zenith. The distance of 52° 42′ 20″ corresponds to the distance the moon will travel during the flight of the projectile. The earth's rotation will give the projectile a sidewise thrust that will carry it some eleven degrees out of line, which must be added to the other figure. The moon, therefore, at the time of firing, will be 64 degrees from the vertical and in the constellation Gemini.

The projectile is to be nine feet in diameter, so that its course can be followed in a powerful telescope built for the purpose. It is to be a hollow sphere of aluminum with walls one foot thick. The cannon is to be built near the 28th degree of latitude in Florida. It is to be 900 feet long, built of cast iron by the process of preparing a well, building a cylinder nine feet in diameter in the center, pouring the metal, removing the cylinder, and polishing the bore. The cannon is necessarily muzzle-loading. It is decided to make the charge 400,000 pounds of fulmicotton, and since 500 pounds of fulmicotton can be compressed into 27 cubic feet, the projectile will still have over 700 feet to travel within the cannon. In dealing both with the cannon and the charge, however, no reasonable method is presented as an explanation for the figures decided upon, and the reader is left with the decided impression that there is no more definite method than to choose a figure impressively higher than any actually involved in historical affairs. Possibly this may be justified in view of the unpredictability of the behavior of matter under much higher pressures and temperatures than we are acquainted with in the laboratory, particularly around 1870, and the treatment is necessary to the story, for the Cambridge Observatory neglected to take into account the resistance of the atmosphere, which, Verne asserts, will reduce the muzzle velocity by one third. The required velocity is therefore 54,000 feet per second rather than 36,000, and it is rather fortunate that the designers of the apparatus are somewhat vague, and under the impression that overestimation is far less of an evil than underestimation.

While the gun is being prepared a Frenchman, Michel Ardan, asks that he be permitted to travel in the projectile. After some discussion this request is granted, and later Barbicane and his personal enemy Nicholl decide to make it a threesome. The projectile is modified to a conic shape, so that it will maintain a constant position and the travellers will be able to stand on the base; for the same reason the gun is not rifled. The projectile must be provisioned, and together with the additional surface of the changed form, the thickness of the walls (but not of the base) must be cut down to keep the weight near the 20,000 pound limit desired. Other problems must also be met: to keep the air healthy potassium chlorate is used to supply oxygen, potassium hydroxide to absorb the carbon dioxide. It is recognized that no springs would be strong enough to cushion against the shock of departure, so a wooden platform is made to float on three feet of water. At the time of departure the water will be forced out of the projectile and the platform sink to the floor. The landing on the moon is to be rendered supportable by retarding the fall of the projectile with rockets.

We now return to the telescope, which, it will be remembered, was to be built specially to render visible on the moon's surface an object only nine feet in diameter. The largest telescope in existence at the time Verne wrote was the Rosse 54-inch reflector: nevertheless the

Cambridge Observatory decides to surpass this by far and build theirs as a reflector of 16 feet diameter with a tube 280 feet in length. The central mirror was suppressed, according to the design of Herschel, the observer taking his position inside the tube itself. To avoid atmospheric interference the telescope is installed on Long's Peak, the highest position available in the United States. The installation is completed three months before the date of the voyage, and is used to determine the apparent diameters of many stars and to reduce the Crab Nebula. But when the time comes for the telescope to be trained on the projectile, clouds produced by the disturbance of the firing prevent any observations.

Solar Eclipse Observed in China under the Shadow of Japanese Bombers

By Y. C. CHANG

The total solar eclipse of September 21, 1941, is not the first eclipse observed by an expedition of Chinese astronomers. Two parties were sent out to observe the eclipse of June 19, 1936: one to Hokkaido, Japan, and another to Khabarovsk, Siberia. One of the countries, which extended so many courtesies to Chinese astronomers during the last eclipse, seemed to have regretted her act of kindness and turned around to occupy a large portion of our land and massacre countless number of helpless citizens. Chinese astronomers were also put to flight from their home at Nanking. The National Institute of Astronomy, Academia Sinica, had to move whatever it could carry to the interior, and establish itself on Phoenix hill, Kunming, Yunnan. However great the odds may seem to be, the spirit of Chinese astronomers has been undaunted. With eight thousand kilometers of eclipse track inside our territory, how could we let this opportunity pass without doing something? Especially since the prevailing war conditions would probably prevent astronomers in Europe and America from sending expeditions over here, those who had the eclipse track right at home would naturally be expected to perform their duty.

The meteorological data collected by Dr. C. S. Yü indicate that northwestern China has the most promising weather, although it is not so easily accessible as the southeastern provinces. There is an air service to the northwest, but the large number of boxes of instruments and personal belongings made this form of transportation out of the question. The only alternative was to go by truck. The motor road to our destination in Kansu province is about 3200 kilometers from Kunming, and the round trip for this expedition took us one hundred and sixty days. At first glance, it seemed that we travelled at a snail's pace of only four kilometers a day, on the average, but war conditions will fully explain this tardiness.

The road along which the expedition party travelled was not strewn with roses, but with wrecked cars and trucks, right and left all the way along—some turned upside down on the roadside, others lying in the precipitous abyss, completely smashed into small pieces. Most of the dilapidated vehicles showed a weather-beaten appearance; but a few accidents happened on the very day when we reached the scene, with fresh blood stains on the ground as a dark warning to those who drove by. Of course the carelessness and incompetence of the drivers were partly to blame. The narrowness of the road, the steep grade, and the rapid succession of hairpin turns conspired to aggravate the situation, and were mainly responsible for the large number of accidents.

Astronomers as a class are not particularly well known for temerity. But familiarity with the march of celestial events, predestined and unalterable, usually temper their philosophy with a certain degree of fatalism. At any rate, in setting out on an eclipse expedition, one had to take a fifty-fifty chance in the matter of weather. So far as the probability was concerned, the chance of a mishap on the road was perhaps only one in a hundred. It is no wonder that we should be able to regard this matter with equanimity.

At present, when everything for victory and for military purposes comes first, we Chinese astronomers should congratulate ourselves on being able to have a truck at all at our service. When the demand for gasoline is so enormous on every side, such a privilege is not easy to obtain. To hire a truck for this observation trip would have cost nearly a fortune, and would have been far beyond the pocketbook of our astronomical institution in war-time China. Fortunately, the government, however busily occupied it was with so extended a war front, came forward to our rescue and set aside a truck at our disposal. We loaded the truck first with boxes of instruments. Above these, we put our bedding and other baggage. On top of all sat the eclipse-hunters, trying to make themselves as comfortable as possible. Although we found ourselves at the mercy of the elements—the blistering sun of the Tibetan plateau and the torrential showers of the upper Yangtze valley, the boundless panorama which we could command from our point of vantage must have been far better than what could be snatched through the windows of a Pullman sleeper. Once given the opportunity to launch upon the eclipse expedition, we would not complain of mere physical inconveniences, well remembering what privations and dangers our heroic compatriots were enduring at the various fronts.

In addition to the danger of car accident along the perilous highway, the threat of aerial bombardment haunted the expedition party on every turn. Over a score of times we had to leave the car and run into hiding places on hearing the siren, giving alarm of approaching enemy bombers. At one time the bomb exploded so close that the truck was covered with an additional layer of dust and mud. Luckily, neither the astronomers nor the instruments suffered any damage, in spite of the

excellent marksmanship.

Dr. C. S. Yü had recommended Tienshui in the province of Kansu for the site of observation. It is more easily accessible. The name Tienshui, when literally translated, means "water from heaven," which is just what eclipse observers try to avoid! We selected instead the city of Lintao, Kansu, for the site of observation, as it held forth somewhat more favorable meteorological possibilities than other places. There the eclipsed sun attained the high altitude of 52° 22′. The Tai-Shan Temple on the slope of a hill, about a mile to the east of Lintao, was selected as the observing ground, since the city with its congested population had

FIGURE 1

Eclipse party in Tai-Shan Temple, Lintao, Kangsu. From left to right: T. H. Pan, K. T. Li, S. M. Kung, Y. C. Chang, Y. T. Hu, C. K. Chen, H. Li, S. K. Kao, Y. T. Chen, Y. H. Ou.

been a favorite target of Japanese air attacks. Our precaution was justified by later events: Japanese planes visited us three or four times during our stay at Lintao. Only once did they drop about a dozen bombs within our sight, which stirred up such a cloud of dust and smoke that it took half an hour to settle down. Even on the morning of the eclipse, word was received from Chungking, the war-time capital of China, about the approach of a squadron of enemy planes. It was not known whether they were out on an excursion to enjoy the glorious spectacle of a total solar eclipse, or bent upon scaring our people into shelter and thus depriving them of this rare opportunity.

A horizontal camera of 6-meter focal length, with triplet objective of 15 cm aperture had been ordered several years ago from Fecker, especially for this eclipse observation. It arrived at Hongkong last July,

but we had not been able to transport it to free China in time for the eclipse. Perhaps it was destroyed during the fall of that island, or it might have been carried away to enrich the equipment of a Japanese observatory. Whatever the case may be, our expedition party was deprived of a powerful instrument for photographing the corona, and had to be satisfied with the apparatus already on hand.

We lacked good instruments for tackling important problems; still, our program covered quite a variety of observations which are usually carried out during a total eclipse of the sun. The observing party consisted of Dr. Y. C. Chang, the director of the expedition; Professor H. Li; Dr. K. T. Li; Mr. C. K. Chen; Mr. S. M. Kung, of the National Institute of Astronomy, Academia Sinica; Mr. Y. T. Chen, of the

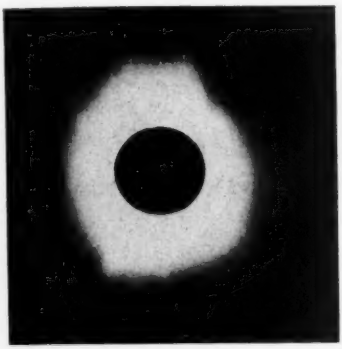


FIGURE 2
Corona of 1941 Solar Eclipse. Exposure 1 sec., without filter.

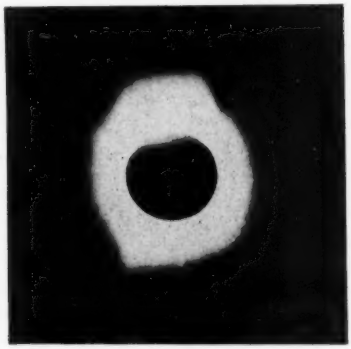


FIGURE 3
Corona of 1941 Solar Eclipse. Exposure 5 sec., with yellow filter.

Meteorological Station of Kunming; Messrs. T. H. Pan; Y. T. Hu; Y. H. Ou, of the University of Nanking; Mr. S. K. Kao, of the National Central University; and Mr. L. Kao, President of the Chinese Astronomical Society. The longitude and latitude of the site of observation were determined by H. Li, C. K. Chen, and S. M. King with an astrolabe à prisme; the result was found to be:

Longitude 103° 52′ 13″.6 E.
Latitude 35° 22′ 33″.1 N.

While making preparations for the observation of the eclipse at Lintao, there was a string of uninterrupted rainy days lasting about a fortnight. Meteorological fears became prevalent among the members of the party. It was also with great difficulty that focuses were obtained and instruments adjusted when we found holes in the clouds. On the morning of the eclipse, everybody was happy to see the sky clear up gradually. It became perfect at the approach of first contact, marred only by a few small drifting patches of cloud at the beginning of the eclipse.

For direct photography of corona, a horizontal camera, with 15 cm aperture and 150 cm focal length, was employed, together with a coelostat. It was operated by H. Li and S. M. Kung. Three plates were obtained with exposures of 1 sec, without filter; 5 sec, with yellow filter; and 30 sec, with red filter.

The total light of corona was measured by the simple means of a Weston exposure-meter connected electrically to a galvanometer. These instruments were in the charge of Y. C. Chang and K. T. Li. The deflection due to coronal light was about 2.0 cm, while the deflection due to full moon observed two weeks afterwards at Langchow was estimated to be about 4.5 cm.

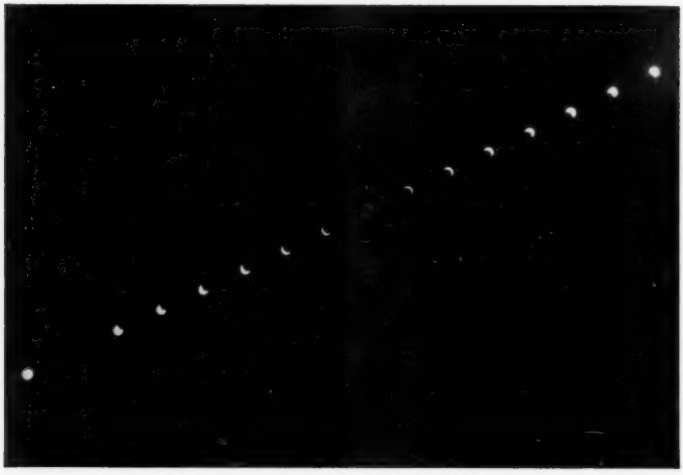


FIGURE 4

Successive Phases of the Total Solar Eclipse, September 21, 1941. Exposure made every ten minutes as the eclipse progressed (from lower left to upper right). The second image of the sun was obscured by a patch of passing cloud.

The times of contacts were observed by projecting the image of the eclipsed sun on a screen. Our chronometer was checked by the time signal from Manila. The observed and computed times (in terms of local standard time for longitude 105° E.) of contacts are as follows:

	Observed	Computed	O-C
	h m s	h m s	s
First Contact	9 29 42.1	9 29 32.3	9.8
Second Contact	10 50 36.6	10 50 38.0	—1.4
Third Contact	10 53 38.8	10 53 37.6	1.2
Fourth Contact	12 18 36.0	12 18 41.0	—5.0

With an Eastman View Camera (F: 4.5, f = 21 cm), a series of images of the eclipsed sun was obtained on the same plate at intervals of

ten minutes, showing the successive phases. The exposures were made by C. K. Chen.

Spectrographic observations of corona and chromosphere were attempted by S. K. Kao, but the result was not very satisfactory. Messrs. T. H. Pan, Y. T. Hu, and Y. H. Ou, each operated a motion picture camera throughout the eclipse. One of them used Kodachrome film, showing the eclipse in all its beautiful natural colors. Mr. Ou made the cinematic picture from a light bomber in the air, as a precaution against possible cloudy weather. Following the practice of American eclipse expeditions, we also broadcast the dramatic spectacle of this eclipse. The message was sent from Lintao to Lanchow by telephone, thence retransmitted to Central Station XGOA, where the broadcast was made.

A group of local student artists were invited to paint the eclipse in watercolors. Two red prominences were clearly indicated in these pictures. Venus, Jupiter, and five stars were reported to be visible to the naked eye at the moment of totality. The phenomenon of shadow bands was particularly striking at this eclipse. Everybody saw them both immediately before the second and after the third contact.

Throughout our stay in northwestern China, the local authorities extended to us the highest courtesies and rendered the most valuable help. Our presence there had also a very wholesome educational influence upon the local people. We were not disturbed during the observation by any beating of the tom-toms or gongs. On passing through bigger cities in the interior of China, on the return trip, we arranged to give more than twenty lectures on the eclipse and astronomy in general. We collected a large number of photographs, drawings, and diagrams concerning eclipses and gave several exhibitions of these to the general public. Both the lectures and exhibitions were very well attended; they stirred up considerable popular interest on the subject of astronomy. Even if this expedition did not acquire results of great scientific value, we hope nevertheless that it has accomplished something for the cause of astronomy.

National Institute of Astronomy, Academia Sinica, Kunming, China,
January 26, 1942.

The Inventor of Standard Time

By R. NEWTON MAYALL

In 1883, the United States and Canada adopted a system of timekeeping we commonly call Standard Time. Many people living today can remember how every town and city of any size had its own Local Mean Time—yet, there are but very few of the present generation who realize or know our Standard Time System is only 58 years old. The rapid changes and progress during those 58 years can be attributed, at least partially, to our lack of knowledge concerning Standard Time—a thing so intimate and so bound up with everyday affairs.

Is it strange that so few of us know anything about time? Time is taken for granted, but it is wholly man-made. When the inventor of Standard Time gave his invention to the world, he presented the peoples of the earth with a gift that transcended all monetary values—its import was far greater than could be accounted for in dollars and cents. It benefited all, regardless of station in life, religion, or race; but do you know who invented the Standard Time System in use today?

Just think a minute about Standard Time—what it is, what it does for humanity as a whole—contrast its orderliness with the confusion existing prior to its acceptance. What would our life be today if every time we travelled between New York and Boston we had to reset our watches in the short space of a few hours!

It is those things we use the most that we know the least about, and similarly we quickly forget the men whose brains and work brought those things to us. Time and Standard Time are in the former category and the inventor of Standard Time falls in the latter. We do not always find the names of such men in our halls of Fame or in our encyclopedias. Notwithstanding the importance of his contribution the name of the inventor of Standard Time will not be found in the Halls of the Great. Only a handful sought to perpetuate his memory by erecting a bronze plaque which extolled his achievements. This was twenty years ago.

Within the past five years, another monument has been erected in Canada, attributing the invention of Standard Time to one of her illustrious citizens—Sir Sanford Fleming. No one would be so base as to deny the honors heaped on this famous Scottish-Canadian; but one of these honors—that of inventor of Standard Time—unfortunately is not for him. I know our friends across the border will not be disheartened when they learn it was a citizen of the United States and not of Canada that conceived our Standard Time System.

In the light of recent events it is obvious that most writers on the subject of Standard Time are ignorant of the historic facts concerning its invention and adoption, or they are unwilling to accept facts. Every

now and then we see historical references to Standard Time that impress us with their validity, yet in almost no instance have these references been based on the large amount of incontrovertible data available in practically any large public library.

One day, a few years ago, I walked into the Boston Public Library for the sole purpose of checking up on the real inventor of Standard Time. I obtained more material in the short space of fifteen minutes, than probably you would care to wade through. However, I have sifted the data and it seems well worth while to set down a few facts concerning—if I may borrow the title of a recent article—the "Birth of Standard Time."

Standard Time was a creation of man and, as such, some one must be credited with its origin. There is little need to go into detail about it, for all know its basic principle that all places within certain areas, called zones, will observe the same time, in reference to a meridian at or near the center of each one called a Standard Time Meridian. We also know that the time in one zone differs from that in its two adjacent zones by exactly one hour.

The question is—who really did invent this system of timekeeping, known as Standard Time?

Most writers credit Sir Sanford Fleming, a Canadian engineer, with the invention; so let us first briefly examine his contributions. There are two significant facts.

First of all, Fleming's biographer relates a story of how, in 1876 (and remember the date) the need for time reform "was first brought home to him." The story was taken from one of Fleming's diaries. And secondly, the same story appears in a paper which Fleming gave before the Canadian Institute in 1878. This is significant, for by his own admission, his interest in the subject of time reform began in 1876.

Now let us examine Fleming's contribution. Originally he was interested in the substitution of a twenty-four-hour day for the two series of twelve hours. This led from one thing to another, and the result of his labors is contained in a memoir called Terrestrial Time, printed for private distribution in 1876. This memoir was later rewritten, expanded, and published. The copy I refer to is dated November 24, 1878.

Briefly, the memoir proposes to have the clocks all over the world indicate the same time at the same moment, which Fleming suggested calling Uniform Time or Terrestrial Time. This system was complicated by his suggestion to add local time on the same dial. On page twenty-three of the memoir he describes how, if his system is adopted, we would use local time for ordinary purposes, and "whenever exact time was required for any purpose, Terrestrial Time would be available." That is, we would make social and business calls by a local time and catch our trains by Terrestrial Time. This is sufficient evidence to fix the time of Fleming's entrance into the picture of time reform and the

nature of his contribution. A little farther on I shall show how he was in total disagreement with previous attempts to introduce our present Standard Time System.

Now let us see what happened prior to 1876. Two important publications were issued in the year 1870—the first was a circular titled "National Rail-Road Time;" the second, a pamphlet of 107 pages, titled "System of National Time for Rail-Roads; A specimen Time Table, and Time Gazeteer for all stations in the United States and Canada." The circular refers to the pamphlet, and the following quotations explain the system.

"The 'System of National Time for Railroads' is founded upon Longitude, hence Washington Time is taken as the Standard Time; but, in order to keep Railroad Time near to Local Time, every Fifteenth meridian from Washington, that is, every meridian marking exact Hour differences of Time from Washington Time, is also taken as a basis for Standard Time, thus:

"Washington Time is taken as the standard for the Atlantic states,
"One Hour Slower than Washington Time, for the Mississippi Valley States,
"Two Hours Slower, for the Rocky Mountain States, and
"Three Hours Slower, for the Pacific States.

"These Standards are designated by the small figures 0, 1, 2, 3, respectively, placed before the names of the Stations. These figures are called *Hour Indexes.* But, instead of using these indexes, the Standard may be designated by stating at the top of a Time Table what time is used."

(Right here you can see the only difference from our present system is the use of the Washington meridian, instead of the 75th.)

"The author having conceived the plan of this system, was invited to lay it before a Convention of Rail Road Superintendents held at New York in October, 1869. Six superintendents, as an informal committee, met him and gave a unanimous approbation of the plan, and offered, individually, to give letters of commendation, if needed, to develop it and carry it into operation. The author, therefore, undertook the work. During its progress he has been in frequent consultation with scientific men, and also with practical Rail Road men.

"One form of the work was completed during the winter, and a careful revision of it was made during the spring and summer. Now, September, 1870, the work has just come from the press. It contains an exposition of the scientific principles involved; an engraved map of the United States, colored to show the Standard or Hour Sections, and a Gazetteer with all the Rail Roads in alphabetical order, and every Station Indexed. It is hoped that it will meet the wants of Rail Road Managers and the traveling public."

The author of this plan was Charles Ferdinand Dowd of Saratoga Springs, N. Y. The following testimonial is a part of the circular.

TESTIMONIAL (SCIENTIFIC)

Mr. Dowd's plan of systematizing the difference of Time and Standards for Railway Time is based upon *correct scientific principles,* and is recommended to the attention of Railway Managers.

TESTIMONIAL (PRACTICAL)

Mr. Dowd's plan of systematizing the differences of Time and Standards for Railway Time seems *simple and practicable,* and worthy of the attention of Railway Managers.

The scientific testimonial was signed by "Elias Loomis, Professor of Astronomy in Yale College; H. A. Newton, Professor of Mathematics in Yale College; G. W. Hough, Director and Astronomer, Observatory, Albany; W. H. C. Bartlett, Professor N & C Phi. Mil. Acad., West Point, and E. Upton, Bv. Maj. Gen. U.S.A. West Point." The practical testimonial was signed by more than twenty railroad superintendents from all parts of the country.

The large pamphlet was the result of much time and effort spent by Dowd during 1869 and 1870. Dowd's system called for the division of the country into zones as early as 1870. All the clocks in one zone would show the same time and differ from those in the two adjacent zones by exactly one hour; thus creating four zones in the United States. This pamphlet with its colored map had a wide distribution, and many are in existence today. The four zones shown on Dowd's map were divided almost exactly as they are today. Here is evidence of Dowd's priority; but there is more significant evidence.

A controversy arose over the use of the Washington Meridian. Some wanted to use the New York City Meridian. The probable cause of this controversy may have been the circular just referred to with its testimonial signatures of scientists and railroad executives. Controversy was all that Dowd needed to bring his plan to final perfection—he then argued for and insisted that the 75th meridian west of Greenwich would be more satisfactory than either the Washington or New York City meridian, for these reasons:

1. It was equally well adapted to conveniently located hour sections.
2. It had the great advantage of conforming to accepted longitude measurements.

He won over those concerned to the acceptance of the 75th meridian west of Greenwich as the basis of time in the eastern section of the United States, with the 90th, 105th, and 120th meridians serving the remaining three sections. A circular calling attention to the acceptance of the new system of dividing the country was published on May 15, 1872. The new system was also the basis of Dowd's "Railway Superintendents' Standard Time Guide" (1877) and the "Traveler's Railway Time Adjuster" (1878).

Therefore, Dowd had, in 1872, published a system of Standard Time, and laid down the Standard Time meridians identical with the system and meridians in use today. Fleming, by his own acknowledgment, did not enter the picture until 1876.

Numerous newspaper articles, from 1870 to 1904, attest Dowd as the inventor of the Standard Time principle. Mr. William F. Allen, in a report to the American Metrological Society (1883) refers to Dr. Dowd's 1870 pamphlet as "the first published proposition of which I have any knowledge." Allen, as editor of the "Railway Guide" and Secretary of the Railway Association was in a position to know.

After much delay and constant work on the part of Dowd, his plan went into effect in the U.S. on November 18, 1883, following which papers all over the country carried long and interesting accounts of the history of Standard Time with great emphasis on the work of Charles F. Dowd, begun in 1869. An enviable tribute to Dowd as the originator of the Standard Time System appeared in the Wall Street *Daily News,* November 16, 1904—four days after his death.

Throughout his life Dr. Dowd was an educator, and for 35 years he guided the affairs of the Temple Grove Ladies Seminary in Saratoga Springs, N. Y., an important seminary of the day. A few of Dowd's former pupils had a bronze tablet erected in his memory. It may be seen in the Presbyterian Church in Saratoga Springs, N. Y., and it bears this inscription—

IN MEMORY OF
CHARLES FERDINAND DOWD, PH.D.
APRIL 25, 1825—NOVEMBER 12, 1904
A ruling Elder of this Church
Wise in Counsel
Prudent in Action, Broad in Charity
AN EDUCATOR
Far-reaching and ever-living in influence
In Solving the Problem of STANDARD TIME
He proved himself a world-benefactor.
As a grateful tribute
This tablet is erected
by his loving pupils.

In addition to this tablet, an excellent book was published in 1930, titled *Charles F. Dowd and Standard Time,* edited by Charles N. Dowd. Within its pages will be found ample proof of Dowd as the inventor of the Standard Time System.

It is almost unbelievable that Dowd's name cannot be found in our reference books; but anyone who takes the trouble to examine the records will come to the same conclusion as the late George Eastman, who wrote in a letter dated July 24, 1928: "I regret that I did not give to your father, Charles Ferdinand Dowd, the credit which was due him as the author of the Standard Time principle. This was an unintentional error which has been noted for future reference. Examination of the record leaves no doubt that he was the pioneer."

However, Fleming's contributions to the subject of time should not be belittled, but let us not confuse the Standard Time System with others such as Uniform, Universal, or Terrestrial Time and similar propositions.

But it must be remembered that Fleming was contemporary with Dowd, and it is apparent that Fleming considered our present system of Standard Time confusing; and that he was not in agreement with the system is shown in the following sentence, extracted from one of his reports made in 1886 (three years after the adoption of Standard Time!):

"At one place it is noon, at another midnight, at a third it is sunrise, and at a fourth it is sunset. In consequence, we have the elements of confusion."

In the light of this, how can anyone attribute the invention of the Standard Time System to one who by his own words was familiar with it, was in disagreement with it, and publicly announced he did not become interesed in time reform until four years after the Standard Time System had been perfected and published by Dowd? Fleming did all these things, yet he is frequently credited with the invention of that which he was not in favor.

Examination of Fleming's papers shows that his system was totally different from that now in use, whereas our present system is identical with that laid down by Dowd as early as 1872.

Dr. Dowd received no monetary gain for all his effort and work, but, according to the Wall Street *Daily News,* November 16, 1904, "in recognition of his claim of inventorship he received annual passes over every great railway and its branches." Surely we cannot let him lie unhonored, and unsung!

It was Charles Ferdinand Dowd who brought comfort to countless millions—order out of chaos. He was the inventor and originator of Standard Time.

Planet Notes for May, 1942

By R. S. ZUG

Sun. Apparent positions of the sun for May 1 and June 1, respectively, are: $\alpha = 2^h\ 30^m.3$, $\delta = +14°\ 48'.8$; $\alpha = 4^h\ 32^m.9$, $\delta = +21°\ 56'.1$. The sun passes from the constellation Aries into the constellation Taurus on May 14.

Moon. Phenomena of the moon will occur as follows:

		h	m
Last Quarter	May	7	12 13
New Moon		15	5 45
First Quarter		23	9 11
Full Moon		30	5 29
Perigee	May	2	7
Apogee		17	15
Perigee		30	16

Mercury. Mercury will reach a greatest eastern elongation of 22° 11′ on May 18 (20^h) an will for a number of days before and after this date be a conspicuous object in the evening sky. At greatest elongation the planet will be situated in

declination +25°, about 5° south of β Tauri. On May 17, $4^h\,18^m$, the planet will be situated 7°.5 directly north of the moon. A knowledge of this fact may assist in enabling one to locate the planet. The stellar magnitude of the planet at greatest elongation will be +0.6.

Venus. Venus will be a morning object during May. The planet will be on the celestial equator on May 9, and by June 1 will have attained a declination of +9°. An occultation of Venus, visible in the southern hemisphere, occurs on May 11. The predicted time of conjunction in right ascension is $11^h\,6^m\,50^s.4$.

Data concerning Venus, of interest to observers, are tabulated below:

Date 1942	Distance from earth in miles	Angular Diameter	Fraction of disk seen illuminated	Stellar Magnitude
April 30	75,498,000	20".7	0.58	—3.8
May 10	82,783,000	18.9	0.62	—3.7
20	89,936,000	17.4	0.66	—3.7
30	96,919,000	16.1	0.69	—3.7

Mars. Mars is in the evening sky and is gradually nearing the sun. It is still favorably placed for early evening observations, however, being $3^h\,40^m$ east of the sun on May 1 and 3^h east of the sun on June 1, the declination varying during the interval from +25° to +23°. In apparent motion, the planet will move from the eastern portion of the constellation Gemini to a point about 8° south of the bright star, α Geminorum (Castor).

Jupiter. Jupiter is still an evening star. By the end of May, however, it will be but one hour from the sun in right ascension. Its declination remains about +23° during the month.

Saturn. Saturn will be in conjunction with the sun on May 23.

Uranus. Uranus will be in conjunction with the sun on May 22.

Neptune. Neptune is situated in the constellation Virgo. It may be found with small telescopes by searching, during May, about 5^m east of and about 13' north of the bright star, β Virginis. An occultation will occur on May 25, visible between latitudes +48° and —23°. The time of conjunction in right ascension is $8^h\,8^m.4$. The conjunction is invisible from the American continents.

Occultation Predictions for May, 1942

(Taken from the *American Ephemeris*)

Date 1942	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION a	IMMERSION b	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION a	EMERSION b	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30', Latitude +42° 30'										
May 2	49 Lib	5.5	6 19.3	—1.6	—0.9	127	7 29.3	—1.8	—0.4	261
3	90 B.Oph	6.5	4 27.2	—1.8	+2.0	61	5 20.1	—0.9	—0.8	325
5	190 B.Sgr	5.4	6 8.2	—1.0	+0.3	123	7 9.5	—1.7	+1.5	238
7	BD—15° 5908	6.4	10 11.1	..	..	7	10 45.1	..	..	319
20	162 B.Gem	5.6	2 29.0	+0.7	—3.0	157	3 0.9	—0.3	0.0	225
27	72 Vir	6.1	3 47.8	—1.9	—0.3	74	4 45.5	—0.9	—2.4	331

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

May 2	49 Lib	5.5	5	58.1	−0.9	−1.4	154	6	50.5	−2.4	+1.2	242
3	90 B.Oph	6.5	4	2.0	−0.7	+1.2	90	5	3.8	−0.8	+0.3	297
5	190 B.Sgr	5.4	6	0.6	+0.2	−1.2	153	6	32.8	−1.7	+3.3	212
5	*d* Sgr	5.0	10	43.2	−1.9	+0.1	81	12	3.2	−1.7	−0.5	262
7	BD—15° 5908	6.4	9	40.4	..	..	1	9	59.8	..	..	333
23	*A* Leo	4.6	6	0.3	−0.3	−0.2	53	6	32.5	+0.5	−2.8	344
24	56 Leo	6.0	5	7.2	−0.5	−1.9	124	6	8.9	−0.3	−1.6	280
27	72 Vir	6.1	3	11.3	−1.9	−0.4	103	4	28.1	−1.5	−1.5	309

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′

May 5	*d* Sgr	5.0	9	46.6	−1.6	+0.9	93	11	4.9	−1.9	+0.6	264
9	81 Aqr	6.4	11	23.3	−0.7	+3.1	23	12	9.6	−1.2	+0.1	301
23	*A* Leo	4.6	5	42.7	−1.1	−1.2	93	6	46.8	−0.2	−2.2	312
24	56 Leo	6.0	4	59.3	−0.3	−3.8	170	5	44.9	−2.3	+0.1	243
24	*c* Leo	5.1	7	28.9	−0.9	−0.4	63	8	10.6	+0.1	−2.8	340
25	*β* Vir	3.8	6	59.9	−0.9	−1.8	122	8	7.0	−0.6	−1.6	285
27	72 Vir	6.1	2	34.8	−0.6	−1.6	155	3	33.7	−2.2	+1.2	258
27	*l* Vir	4.8	3	11.1	−2.4	+1.9	72	4	4.5	−0.7	−2.4	343

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

FIREBALL OF 1940 JANUARY 31

On the evening of this date at 5:55 P.M., E.S.T., before it was totally dark, a brilliant fireball was seen to the southeast of Upper Darby by Geo. W. Wetherill, Jr., who is an active A.M.S. member. When I received this information by phone, I informed the local papers, and next day a request for reports appeared in several. In all, about 70 people sent in their observations or impressions, and the results below are based upon them. Due to the large number, it is impracticable to mention each by name, so a general acknowledgment is made to all those who so kindly cooperated and thus made the solution possible. Though the path was wholly over the ocean, off the New Jersey coast, by ill fortune no report from any ship was received. Such a report would have been most valuable. All the available observations were from eastern Pennsylvania, northern Delaware, and south or central New Jersey except one from a girl, Miss Coreta E. Cushman, of Poughkeepsie, N. Y., who fortunately had studied astronomy and had a good knowledge of angles and directions. Wetherill's observation first, and hers secondly, form the cornerstone of the solution. Fortunately others were corroborative

but the value of our results would be cut probably to less than one half were these two missing. The method used was that of plotting the observed azimuths of the beginning point and, in this case, what appeared to be the explosion point or disintegrating point. Many said that the particles fell into the ocean; in general these observers were nearer the path. Those at a distance are certain that it ended in an explosion, and give angular heights which agree fairly well. I have therefore taken the explosion point as that for which solution can be made. If the other observers are right, there were only smaller fragments which continued their course to the ocean. These might well be invisible to persons at a greater distance. The best observers, and some of the others, sent in drawings or reports showing a most distinctly curved path, concave to the horizontal plane. I first joined the beginning point and explosion point by a straight line and used that as the path—actually it is only the chord of the arc. The one error that this introduces is that the altitude of the radiant is much too high. Even for this solution, designated A, the zenith correction, assuming parabolic velocity, was very large, *i.e.* —7°.6. In the second solution for the radiant, designated B, I took the angle on Wetherill's drawing, which evidently had been made with much care on a regular meteor map, between the chord and the tangent at the beginning point. This decreases h by 19°, yet I believe represents the truth better. Also this would give a zenith correction of —11°.1 and would mean that the fireball started on a much more nearly horizontal path and, with its probably low relative velocity, might curve more readily than had the radiant been high over the horizon.

In no case that I have dealt with has relative nearness to the path had more effect on apparent brightness of the fireball and on the visibility of the smoke train left after the body had disappeared. As to the latter, its presence so complicated the estimated duration of flight that attempts to calculate the velocity are useless, the data being extremely contradictory. The estimated brightness and diameter vary from brighter than Venus to ⅔ that of the full Moon. On the whole, it would seem that the body actually "burst" or at any rate had a sudden and enormous increase in light at the point chosen for computation. A great majority give blue as the color; some mention red in the train, others say it was made up of flame and smoke. One says "the smoke settled down," indicating motion. As it was not quite dark, probably the train comes properly under the heading "smoke train." It may have been visible for 20 seconds. An interesting observation was made by E. P. Loveland near New Egypt, New Jersey. He says ". . . returning home . . . car radio was playing and heard a terrific crackling noise from the radio and at the same time saw this meteor . . ." This fully confirms our belief that the passage of a large meteor produces effects on radio reception. In computing the heights I finally used 8 observations for each end, and the deviations from the means are smaller than usual. Indeed, considerable confidence can be had in the solution.

Date	1940 Jan. 31/32, 5:55 P.M., E.S.T.
Sidereal time at explosion point	40°.5
Began over	λ 73° 38′ W; ϕ 39° 05′ N; at 90.2 ± 8.2 km
Ended over	λ 73° 14′ W; ϕ 39° 38′ N; at 37.0 ± 8.6 km
Length of path	88 km
Projected length of path	70 km
A Radiant (uncorrected)	$a = 29°$, $h = 37°.2$ $\alpha = 17°.5$, $\delta = -8°.6$
A Radiant (corrected)	$a = 29°$, $h = 29°.6$ $\alpha = 14°.6$, $\delta = -15°.5$
B Radiant (uncorrected)	$a = 29°$, $h = 18°.2$
B Radiant (corrected)	$a = 29°$, $h = 9°.2$ $\alpha = 4°.0$, $\delta = -36°.1$

In the von Niessl-Hoffmeister Catalog, No. 37 and No. 42 are probably near enough as to day of the year and radiant to be comparable with A, when the inherent uncertainties of fireball paths are remembered. If we adopt B, however, there is no longer the slightest resemblance.

Fireball of 1929 July 10

This fireball appeared at about 9:50 P.M., E.S.T., over western Ohio, moving from south to north. The time given may be as much as 10 minutes in error. Turning back to "Meteor Notes" for January, 1930, the following is quoted, which in many ways speaks for itself: "O. E. Monnig of Ft. Forth, Texas, whose aid has been so invaluable in following up fireball observations, has gathered by correspondence and sent in a fine lot which refer to the brilliant meteor of July 10 at 9:45, which appeared over Ohio. He has already done most of the work on this and as soon as possible it will be completed and published." Alas! I am afraid that many similar promises as to meteor records remain in the realm of good intentions, but these delays often can not be avoided. I am now, however, seeking to clear up and publish some of these older cases, all too long delayed.

Monnig sent in nine reports and one other was found in our files. Two reports contain plots of the path, one by G. H. England at Fostoria, Ohio, the other by Mr. and Mrs. Kouder and their son at Ft. Wayne, Indiana, (two plots here, mean taken). The former did not see the true end point, the latter group apparently not the exact beginning point, but one somewhat along the path. The other reports could be used to check the slope and general direction only. The altitudes calculated from the plots show that those made by "dead reckoning," even by the same people, were far too large. I was therefore over-optimistic 12 years ago about getting a good solution, though, to be just, Monnig then warned me by letter it could not be done. So now by a series of rough approximations the following results are submitted as the best that I can derive from the observations.

Date	1929 July 10/11, 9:50 P.M., E.S.T.
Sidereal time at end point	247°
Began over	$\lambda = 84°\ 33'$, $\phi = 40°\ 30'$ at 59 km
Ended over	$\lambda = 84°\ 27'$ $\phi = 42°\ 00'$ at 15 km
Length of path	171 km
Projected length of path	166 km
Radiant (uncorrected)	$a = 3°$; $h = 20°$; $\alpha = 243°$; $\delta = -28°$

There is no agreement as to the fireball's color, various ones being given, in some cases several by one observer. The majority favor, however, one nearer the red than the blue end of the spectrum; yellow-red is probably correct. The estimated durations range from 3 ± 1 to 20 seconds, most nearer 20, however. The evidence is that it was in sight for a good while, I should say at least 8 seconds. But this figure is only an estimate and can not be used to derive a velocity. The fireball was large and bright, with an apparent disc. It did not explode. It seems to have curved sharply downward at the end of its path. As allowance for this was impossible, due to the incomplete data, I have had to ignore it in calculating the length of path and its slope. This fact makes the radiant's altitude somewhat too great. Its effect is almost wholly in the declination of the radiant point, any correction putting that farther south. The introduction of the zenith correction also ignored for causes mentioned, would further increase the southern declination. There is general agreement among the observers that the path made only a small

angle (if any) with the horizon. The train was described as made up of small red particles and visible 5 to 7 seconds. The phenomena exhibited by this fireball are rather typical of many seen in the early evening hours and which have an almost horizontal path.

Fireball of 1931 January 22

On this date at 6:01 ± 1 P.M., E.S.T., a large and brilliant fireball was seen to cross Pennsylvania from south to north. It appears to have begun over Maryland and ended in northern New York, near the Canadian border. Some preliminary work was done by me on the 46 reports brought in by prompt local publicity and on those added by the late W. J. Fisher of Harvard Observatory who sent me 14 received by him from New England. These 60 reports came from Delaware, Pennsylvania, New Jersey, New York, Vermont, and Massachusetts. Later, I turned over the reports to my former assistants, Mrs. D. M. Wills and Franklin W. Smith, both of whom had had practice in the reductions of meteor paths and were valued members of the staff. However, after considerable work, they were unable to get any solution that was satisfactory to them, and the whole matter was laid aside for many years. During the past month, I have taken it up again and, with the aid of what was done by those mentioned, have worked out a rather good path. My success is due frankly, to a ruthless weighting and rejection of reports when internal evidence and long experience indicated to me that such steps should be taken.

We have the misfortune that few of the observers referred the path to stars. Those who did generally used whole constellations, and in one or two cases certainly misidentified them. The rest of the altitudes and azimuths are based upon "dead-reckonings" or in some cases drawings. These latter have been interpreted as best I could. We find of course the usual phenomenon of over-estimation of altitudes whenever the observer sent in a drawing or star-map by which his estimation could be checked. But such a large number not only wrote original letters but also filled out our questionnaire that the sum total of information, properly handled, has been better than usual.

The maps prepared by Mrs. Wills were first used by me for a preliminary solution though the scale was smaller than desirable and the convergence of the meridians not allowed for. These proving unsuitable, a larger map on proper scale and projection was prepared. Having plotted the azimuths of both the beginning and end points, after study the most probable positions were chosen and the projected path drawn. That several observers reported a vertical path or one passing through their zenith was here of particular service. It is believed that the azimuth of the path, and hence of the radiant, is determined well within ±5°, probably within ±2°. A very nearly horizontal path was insisted upon by observers far to the sides and the data given by others all indicate that the slope was very small indeed. It is only 2½° but when the very large zenith attraction (on assumption of parabolic heliocentric velocity) is allowed for, the radiant was actually below the horizon. Most agree on the fireball's color being reddish-yellow. Drawings and descriptions indicate a flaring tail a few degrees long of about the same color as the fireball itself. The object was shaped very much like a brilliant comet with a short curved tail. For the duration, 24 estimates ranging from 5 to 20 seconds have been used. The average value is 12.4 ± 3.2 sec. This gives an apparent velocity of 42½ km/sec. which seems high for a fireball whose (uncorrected) radiant was about 129° from the meteoric apex. Estimates of bright-

ness or size—it is often impossible to distinguish which is meant—run from that of Mars to that of the full Moon. Its visibility over so great an area proves that it must have been very brilliant, and to many of the nearer stations probably it did give about the light of the quarter Moon. Some observers, far to the side of the path, report sudden changes of brightness or flarings up of the object. They would be in the best position to see such a phenomenon if it occurred. One of the best observers reported that about half way along the course as seen by her, *i.e.*, about at the actual ¾ point, a fragment was thrown off, the fireball continuing, though faint; it then brightened and faded again at the end. Such changes doubtless complicated the determination of the end point, particularly for observers near the south end of the path. One observer said it burst and then went on farther. This refers evidently to a flare. Most say it did not explode. Another observer in a house said: ". . . heard a strange sound that came over the radio. I have never heard a sound on the radio like it." This was simultaneous with the appearance of the fireball. The beginning height depends upon 15 altitudes, the end upon 17, and besides there are 4 others along the path which help to check the heights. The results follow:

Date	1931 Jan. 22/23, 6:01 P.M., E.S.T.
Sidereal time at end point	31°
Began over	76° 12′ W : 39° 16′ N at 112.4 ± 32.3 km
Ended over	75° 30′ W : 44° 00′ N at 89.4 ± 18.4 km
Length of path	527 km
Projected length of path	526 km
Apparent velocity	42.5 km/sec
Radiant (uncorrected)	$a = 7°$; $h = 2° 30'$
Zenith correction	$-10° 45'$
Radiant (corrected)	$a = 7°$; $h = -8° 15'$; $\alpha = 19°$, $\delta = -54°$

Because of the large number of observers, it is impracticable to give the names and stations of each. To their interest in science we owe the data for our results. To them, an the two members of our staff who did preliminary work, I desire to express my sincere appreciation.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1942 March 14.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, Los Angeles, and Department of Astronomy, University of Southern California, Los Angeles

Synthetic Symmetry in Mutual-Induction Balances: A Practical Problem with Meteorite Detectors*

The writer wishes to express his appreciation to Dr. Lincoln La Paz of the Department of Mathematics of the Ohio State University for valuable suggestions made in the course of the preparation of this paper.

*Presented at the Eighth Meeting, Flagstaff, Arizona, June, 1941.

By FRANKLIN OTIS WISMAN
Aircraft Armament Engineering Laboratory, Bendix Aviation Corporation, South Bend, Indiana

ABSTRACT

As has been pointed out in a paper by Dr. Lincoln La Paz recently published in these CONTRIBUTIONS (*P. A.*, **50**, 157-165, March, 1942), efforts to apply electromagnetic detectors to the problem of locating buried iron meteorites have encountered many difficulties inherent in the instruments employed. In an instrument recently devised by the author, some of these difficulties are eliminated. The new detector has only half the weight and bulk of any comparable instrument, and power-supply requirements have been materially decreased. The purpose of this paper is to derive the fundamental relations that must be observed in the design of such an instrument.

The Theodorsen type of metal detector developed by the National Advisory Committee for Aeronautics† for the location of unexploded bombs at Langley Field, Virginia, is one of the simplest and at the same time one of the most sensitive metal detectors ever devised. It consists of a power coil excited with alternating current and 2 identical pick-up coils symmetrically located with respect

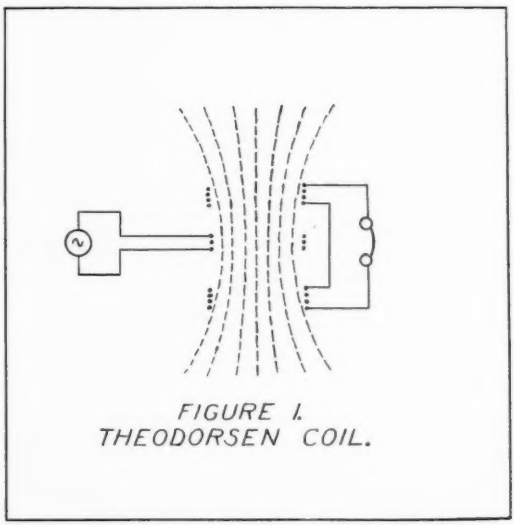


FIGURE 1.
THEODORSEN COIL.

to the power coil and connected differentially in series. When there is no metal in the field of the power coil, that field is perfectly symmetrical, and the 2 induced voltages in the pick-up coil are exactly equal and opposite. No current flows in the telephone receiver. See Fig. 1. If, however, there is in the field any material to cause it to be distorted, then, in general, the induced voltages will no longer balance, and an indication will be given by the ear phone. On account of

†Theodorsen, T., *Jour. Franklin Inst.*, **210**, 311, 1930.

the exact electrical and mechanical symmetry of the coil construction, the balance is not affected by variations in the alternator-supply frequency. This fact is the most common fault of inductometry-type detectors. The Theodorsen search coil with the 2 pick-up coils is very bulky to handle, and it is obviously an improvement if size, weight, and cost of the equipment can all be cut simultaneously without sacrificing performance.

The obvious plan that comes to mind is simply to remove one of the pick-up coils and obtain an equivalent neutralizing voltage with some sort of transformer. It was felt that this transformer might be provided with variable coupling and a phase-shifting network so as to match the search-coil voltage vectorially and to make the complex sum equal to zero. The imagination immediately seizes upon the idea that this transformer might be built very compactly with a steel core and hence with a very slight external field. However, a moment's reflection will disclose the practical impossibility of that construction. The steel would introduce harmonics into the secondary voltage and would make it impossible to get anything approaching a balance, since, if a sinusoid be added to a distorted

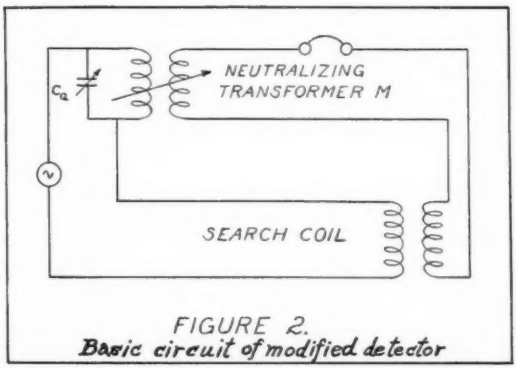


FIGURE 2.
Basic circuit of modified detector

wave, the result cannot possibly be zero. One is therefore restricted to an air-core transformer. It is simple to design a suitable transformer, since the mutual inductance required is of the order of magnitude of only a few milli-henries. The circuit of the suggested arrangement is given in Fig. 2. The theory of operation is that the magnitude of the neutralizing voltage is controlled by changing the coupling of M, and small phase shifts can be effected by adjusting the condenser C_0. The performance of this circuit is as disappointing as the circuit is simple. The difficulty is that we have neglected the effects of distributed capacitances in coil windings and the effects of harmonic content in the power supply, as well as the conductivity of material in the magnetic fields of both search coil and neutralizing transformer M. In general, the circuit will not balance at all unless

it is fed with an exceedingly pure wave form. Even if the wave form is a perfect sinusoid, the balance is lost when the generator frequency varies slightly.

Let us examine what happens in the secondary circuits of both the search coil and the neutralizing transformer. Let the distributed capacitance be represented by an equivalent lumped capacitor across the coil terminals. Let also the resistance be lumped and the induced voltages be constant. Let us draw equiva-

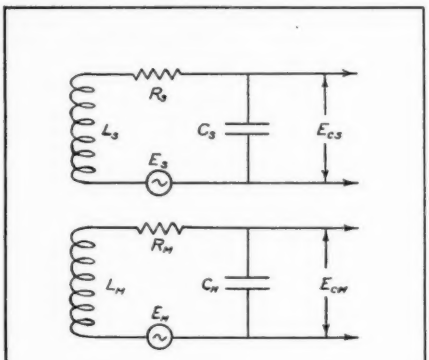


FIGURE 3.
EQUIVALENT SECONDARY CIRCUITS.

lent circuits for the search coil and for the transformer secondaries. The coefficient of coupling is sufficiently small that, for the moment, we may neglect transformed impedances. For these circuits we may draw vector diagrams. Taking E_s and E_m as references, let us assume that R_s, L_s, and C_s are different from their corresponding values for M. The subscript m denotes transformer quantities

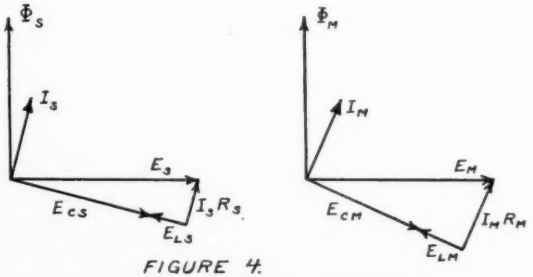


FIGURE 4.
VECTOR DIAGRAMS FOR FIGURE 3.

and the subscript s denotes search-coil constants. From the diagram it is seen that one of the fluxes must be shifted in time by means of C_Q in order to make the vector directions of E_{cs} and E_{cm} the same. See Figs. 3 and 4.

Let us consider what will happen if the frequency is increased. There will be a larger shift in each case, but not equal shifts, because of the effects of unequal circuit impedances. Hence, the apparatus can be balanced at one frequency only. Any harmonics in the signal will remain unbalanced. However, in the case of the original 3-coil Theodorsen apparatus, the balance was valid for all frequencies because of the exact symmetry (physical as well as electrical) actually existing in the coil construction. In the case of the proposed apparatus, it will be necessary to effect a *synthetic symmetry*. Mathematically:

(1) $I_s = E_s/(R_s - j[X_{cs} - X_{ls}])$; $I_m = E_m/(R_m - j[X_{cm} - X_{lm}])$, (3)

(2) $E_{cs} = -jX_{cs}E_s/(R_s - j[X_{cs} - X_{ls}])$;

$E_{cm} = -jX_{cm}E_m/(R_m - j[X_{cm} - X_{lm}])$. (4)

For conditions of balance it is desired that these 2 voltages (see equations (2) and (4), *ante*) be equal; *i.e.*, that

(5) $-jX_{cs}E_s/(R_s - j[X_{cs} - X_{ls}]) = -jX_{cm}E_m/(R_m - j[X_{cm} - X_{lm}])$.

Expanding and separating real and imaginary parts, we have:

(6) $X_{cs}E_sR_m = X_{cm}E_mR_s$;

(7) $X_{cs}E_sX_{cm} - X_{lm}E_sX_{cs} = X_{cm}X_{cs}E_m - X_{ls}X_{cm}E_m$.

Hence:

(8) $$\frac{X_{cm}R_s}{X_{cs}R_m} = \frac{E_s}{E_m} = \frac{X_{cm}(X_{cs} - X_{ls})}{X_{cs}(X_{cm} - X_{lm})};$$

$$R_s(X_{cm} - X_{lm}) = R_m(X_{cs} - X_{ls});$$

or, at a frequency $\omega/2\pi$,

(9) $R_s/\omega C_m - \omega L_mR_s = R_m/\omega C_s - \omega L_sR_m$;

(10) $R_s/C_m - R_m/C_s = \omega^2(R_sL_m - R_mL_s)$.

Now if a balance is to be reached which will be valid at all frequencies, this equation (10) must be satisfied independently of ω. Hence, the coefficient of ω^2 must be equal to zero; *i.e.*,

(11) $R_sL_m - R_mL_s = 0 = R_s/C_m - R_m/C_s$.

Hence,

(12) $R_m/R_s = L_m/L_s = C_s/C_m$.

When these relations are maintained, the secondary balance will be found to be independent of irregularities in the power-supply oscillator. The importance of this relationship arises not so much from the problem of oscillator stability, altho it does simplify the power-supply requirements. The important consideration is that *the fundamental signal note and any harmonics are balanced simultaneously.* We shall deal later with ways and means of applying this relation to design.

The foregoing derivation was predicated on the assumption that E_s and E_m were in phase, and hence that Φ_s and Φ_m were in phase. These fluxes are determined by the primary current. Here again we have 2 *RLC* circuits in series, but this time the line current is the common quantity and it is desired to match current-direction vectors. We shall use the same notation as before, except that

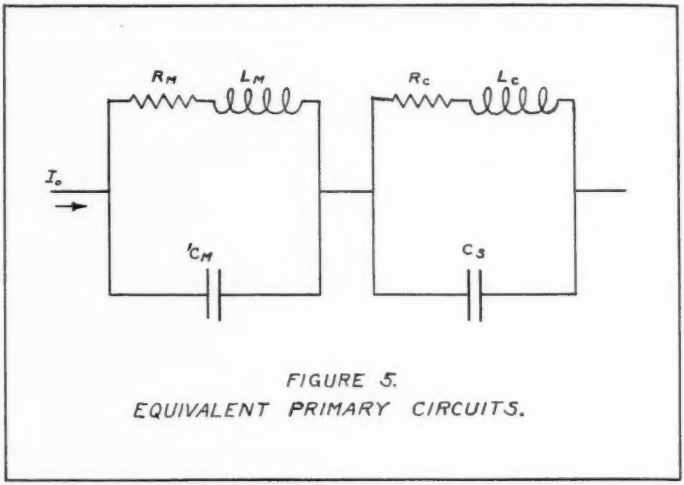


FIGURE 5.
EQUIVALENT PRIMARY CIRCUITS.

now *primary* quantities will be referred to. See Fig. 5. The vector diagram for one of the circuits is given in Fig. 6. The diagram for the other circuit is similar.

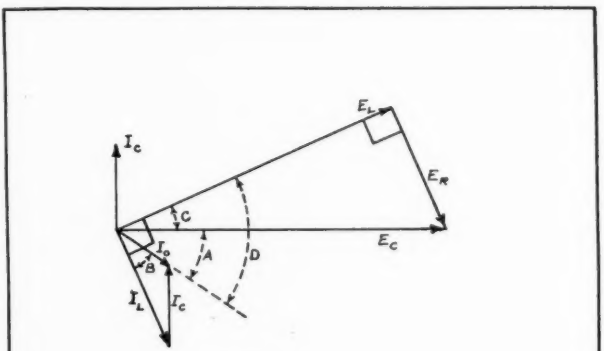


FIGURE 6.
VECTOR DIAGRAM FOR PRIMARY CIRCUIT.

Since magnitudes are easily altered, it will be sufficient to proportion the constants of the circuits so that the vector directions will be the same for each circuit. L_o is the common quantity between the 2 circuits and $\angle B$ is the phase displacement. Observe that $\angle B = 90° - D = 90° - A - C$. $\angle C$ is approximately $1/Q$ radians and is assumed equal for both circuits. It will be shown later that the result validates this assumption. The $\angle A$ is the power-factor $\angle$ that the circuit

presents, viewed as an impedance from the outside. The impedance is:

$$Z_m = [-j X_{cm} R_m + X_{lm} X_{cm}]/[R_m + j (X_{lm} - X_{cm})];$$
$$Z_s = [-j X_{cs} R_s + X_{ls} X_{cs}]/[R_s + j (X_{ls} - X_{cs})]. \tag{13}$$

Now if we expand and separate the real and imaginary parts of these expressions, their quotient will be the tangent of the power-factor $\angle A$ in which we are interested.

$$\tan A_m = [-R_m^2 + X_{lm} (X_{lm} - X_{cm})]/X_{cm} R_m. \tag{14}$$

The expression for tan A_s is similar.

Since we have assumed that the $\angle$'s C are equal, it will be necessary to make merely the $\angle$'s A equal. Therefore, tan A_s = tan A_m; or,

$$(X_{cm} X_{lm} - X_{lm}^2 - R_m^2)/X_{cm} R_m =$$
$$(X_{cs} X_{ls} - X_{ls}^2 - R_s^2)/X_{cs} R_s. \tag{15}$$

Expanding and substituting the frequency $\omega/2\pi$, we obtain:

$$[L_m R_s - L_s R_m]/C_m C_s + R_m R_s^2/C_m - R_s R_m^2/C_s =$$
$$\omega^2 (L_m^2 R_s/C_s - L_s^2 R_m/C_m). \tag{16}$$

If the coefficient of ω^2 is zero,

$$L_m^2 R_s/C_s = L_s^2 R_m/C_m; \tag{17}$$

whence,

$$L_m C_m = L_s C_s \text{ and } R_s C_s = R_m C_m; \tag{18}$$

or

$$R_m/R_s = L_m/L_s = C_s/C_m, \tag{20}$$

(19)

which is identically equal to the result for the secondaries. We see also that our assumption of equal $\angle$'s C is justified, since $Q = \omega L/R$.

We have now a set of fundamental design relations which must be observed if synthetic electrical symmetry is to be achieved. When that symmetry obtains, the apparatus is free from aberrations due to irregularities of the power supply.

In order to insure that the resistance ratios shall hold for all frequencies, it is desirable that corresponding windings of search coil and transformer shall be wound with the same size wire. The inductance ratio must be designed into the windings and the capacitances may be corrected by adding lumped capacitors across the coil terminals.

It remains to balance the system for conducting material which must lie inevitably in the fields of the secondary circuits. The effect of conducting bodies in the field can be analyzed in this manner. Let the generating flux set up by the power coil be equal to $A \cos \omega t$. Then the induced Foucault E.M.F. is $e = -A \omega \sin \omega t$, and $I = e/Z$, where I is the current and Z the total electrical impedance of the Foucault current path. In general, Z will have a small angle, and we see that metal in the field adds a component of magnetomotive force in the negative quadrature direction and that superposition of this component on the impressed magnetomotive force produces a phase shift that is proportional to frequency. From Fig. 7, we see that the effect of this vector addition is to shift the flux and hence the induced voltage in the pick-up coil (secondary) forward with respect to the primary current. In the secondary circuit, a phase shift is effected, which looks as tho an additional capacitance were shunted across the coil terminals. This can be compensated simply by adjusting the capacitor used to correct the symmetry of the secondaries, or, in a practical design, it is sometimes cheaper and

more convenient to replace that capacitor with a piece of copper which rotates into or out of the transformer field. The balancing control then consists of 2 parts, operating on complex axes nearly in quadrature with each other: the direct component, which is controlled by varying the coupling of the transformer, and the quadrature component, which is controlled by the condenser or the piece of copper.

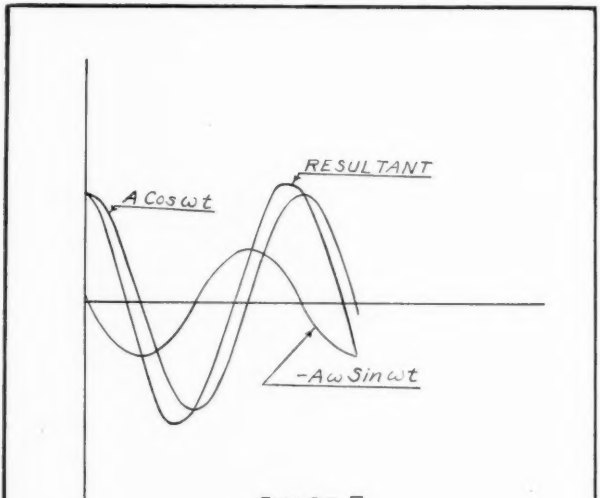


FIGURE 7.
PHASE SHIFT
CAUSED BY FOUCAULT CURRENTS.

The principal value of the relations developed herein is that they form the basis for the design of a stable detection system which is more flexible than its predecessors. The original apparatus built by Theodorsen utilized a search coil which required 2 men to carry it and was powered by a massive gasoline-driven alternator mounted on a large truck. A portable detector designed and built by Dr. Lincoln La Paz of the Ohio State University and the author weighs just 15 pounds and is powered from dry cells. The battery drain (including power used in driving a 100-decibel gain amplifier) is less than 2 watts. The performance that results from using a search coil not much bigger than a man's hat is comparable to that of the large Theodorsen apparatus.

Committee Appointments

The President has appointed the following committees:

Committee on Catalog: Mrs. Addie D. Nininger, Denver, Colorado (Chairman); Oscar E. Monnig, Forth Worth, Texas; S. H. Perry, Adrian, Michigan; L. J. Spencer, London, England; R. C. Vance, Pittsford, New York; and W. T. Whitney, Claremont, California.

Committee on Membership and Fellowship: Robert W. Webb, Los Angeles, California (Chairman); Robert G. Brown, Fort Worth, Texas; J. D. Buddhue, Pasadena, California; Clyde Fisher, New York, New York; Miss Leota J. La Paz, Columbus, Ohio; H. H. Nininger, Denver, Colorado; J. Hugh Pruett, Eugene, Oregon; and Lincoln La Paz, Columbus, Ohio, and C. H. Cleminshaw, Los Angeles, California, *ex officiis.*

Committee on the Proposed Canyon Diablo, Arizona, National Monument: L. F. Brady, Mesa and Flagstaff, Arizona (Chairman); Brandon Barringer and D. Moreau Barringer, Philadelphia, Pennsylvania; G. M. Butler, Tucson, Arizona; Clyde Fisher, New York, New York; F. R. Moulton, Washington, D. C.; and C. O. Lampland and C. W. Tombaugh, Flagstaff, Arizona.

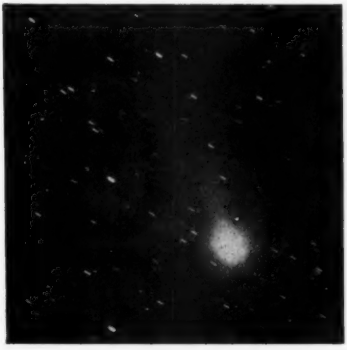
Committee on Terminology (additional members): C. O. Lampland, Flagstaff, Arizona, and Edward S. C. Smith, Schenectady, New York.

C. H. CLEMINSHAW, *Secretary*

Comet Notes

By G. VAN BIESBROECK

COMET 1942 *a* (WHIPPLE). As was foreseen, this comet has brightened up considerably since its discovery on January 25. The increase in brightness has been even greater than was expected from the first computation. Cloudy weather here has made the record very incomplete but on February 23 with the help of a binocular I estimated the total brightness as equivalent to a star of magnitude $6^{M}.4$. Last night, March 10, the figure came out $5^{M}.8$ while the corresponding ephemeris magnitudes were 7.8 and 7.3. Naked-eye visibility has therefore been reached and will almost certainly continue for the balance of this month. Even in a small telescope the comet can be seen as a fairly large coma, with a bright stellar nucleus, and an extension to the north making a coarse tail some half a degree in length. Photographic images have further revealed the presence of a rapidly changing slender and twice longer tail pointing southwestward during



COMET 1942 *a* (WHIPPLE)
March 10, 1942.

February. The plate obtained on March 10 from which the figure is reproduced here shows the broad tail pointing somewhat east of north and the slender tail some 45° farther to the east giving the comet the appearance of a V of 45° aperture. The most curious phenomenon in this case is the fact that the tenuous, fine tail is oriented in the direction opposite to the sun and is therefore the normal tail while the much brighter tail that is seen at first sight is really an abnormal one making a big angle with the direction away from the sun.

It will be of interest for observers to keep a record of these varying appearances while the comet is moving southward and receding. The preliminary orbit by R. N. Thomas still represents the motion of the comet sufficiently well so that it can be extended from p. 167:

EPHEMERIS OF COMET 1942 *a* (WHIPPLE)

	α	δ	Distance from		
0^h U.T.	h m	° ′	Sun	Earth	Mag.
1942 Apr. 7	7 31.6	−18 45	1.49	0.95	6.3
11	21.7	20 11	.47	1.01	.4
15	13.6	21 27	.46	1.07	.5
19	7.0	22 36	.46	.13	.6
23	7 1.6	23 39	.45	.20	.7
Apr. 27	6 57.3	24 37	.45	.26	.8
May 1	53.8	25 33	.45	.31	6.9
5	51.4	26 27	.45	.37	7.0
9	49.0	27 20	.45	.42	7.1
13	47.5	28 13	.46	.47	7.2
May 17	6 46.4	−29 6	1.46	1.52	7.3

The magnitude was adjusted so as to represent the estimate given above for March 10. After April 30, when point nearest the sun is reached, the comet will fade more rapidly and besides the increasing southern declination will reduce the visibility for northern observers. After the middle of May the comet is best situated for southern observers who will have the opportunity to follow this comet probably for several months.

PERIODIC COMET SCHWASSMANN-WACHMANN 2 is gradually fading and moving into the evening sky. On March 10 I estimated the magnitude as 13. The diffuse coma spreads out into a short broad tail in the second quadrant.

The expected PERIODIC COMET GRIGG-SKJELLERUP will probably be picked up before long. Cloudy skies have interfered with the search here.

The search ephemeris given by the English computer Cripps is continued here from p. 168.

EPHEMERIS OF PERIODIC COMET GRIGG-SKJELLERUP

	α	δ
1942	h m	° ′
Apr. 7	5 48.8	+ 2 54
15	6 4.6	4 39
Apr. 23	23.1	6 36
May 1	6 44.5	8 51
May 9	7 9.0	+11 36

During April the comet moves across Orion and is therefore well placed for evening observations.

Williams Bay, Wisconsin, March 10, 1942.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Light Curves of Long Period Variables, II: Following along the lines of discussion of the mean light curves of long period variables published in these notes for February, we present the curves of 25 more variables. The data in Table I are presented in the same form, with the addition of a column giving the mean magnitude at maximum. The total number of observations involved in this installment is 50,229, or an average of 2,000 per variable, with the minimum number of 198 for S Arietis, apparently a difficult star to observe, and a maximum of 11,096 for *o* Ceti, probably the most assiduously observed long period variable of all. For purposes of comparison, the mean values found for the first discussion are here repeated in the line marked I, followed by the means for the 50 stars so far discussed.

TABLE I

Design	Name	No. Obs.	No. 10[d] Means	A/D	M/m	Per. d	—Av. Dev.— Max. d	Min. d	Mag. Max.	Range M	Type
011272	S Cas	1820	432	0.66	0.59	612	12.4	15.0	9.0	6.0	Cd
011712	U Psc	422	237	1.15	1.29	173	4.6	4.6	11.2	2.9	Ac
012350	RZ Per	1447	522	1.12	1.54	354	7.2	6.5	9.4	4.1	Ad
012502	R Psc	964	300	0.61	0.67	344	11.9	11.4	8.2	6.0	Cb
013238	RU And	1000	434	1.32	1.48	237	4.8	6.2	10.6	2.8	Ad
013338	Y And	868	357	0.74	0.76	220	6.5	5.6	9.2	5.1	Cb
014958	X Cas	1108	480	1.12	0.74	425	11.0	10.0	10.7	1.8	Cd
015254	U Per	4253	652	0.80	1.96	318	11.8	10.8	8.3	2.6	Ad
015912	S Ari	198	146	0.68	0.37	295	6.5	7.8	10.9	4.2	Cb
021024	R Ari	3113	523	0.99	1.17	187	4.4	4.6	8.2	4.5	Aa
021143a	W And	2311	460	0.61	0.58	397	5.3	6.3	7.5	6.2	Cd
021281	Z Cep	874	316	0.86	0.62	280	6.0	5.3	11.0	4.4	Cb
021403	*o* Cet	1196	558	0.53	0.70	331	7.4	9.2	3.7	5.5	Cb
022000	R Cet	1283	340	0.83	1.15	167	4.5	5.0	8.2	4.5	Ab
022150	RR Per	968	390	0.70	0.49	391	5.9	13.2	9.5	4.8	Cb
022426	R For	528	351	0.96	0.98	387	8.6	10.8	8.6	3.3	Ba
022813	U Cet	891	323	0.78	1.28	235	5.0	4.7	7.5	5.2	Ab
022980	RR Cep	1021	357	0.78	0.22	385	8.6	11.4	10.4	4.6	Cb
023133	R Tri	5637	561	0.78	0.90	266	5.6	4.8	6.3	5.3	Cb
024217	T Ari	1816	392	0.95	2.63	314	7.4	8.6	8.6	2.0	Aa
025050	R Hor	2069	594	0.55	0.75	401	6.1	6.8	6.0	7.0	Cb
025751	T Hor	1078	482	1.10	0.92	218	6.5	6.7	8.3	4.9	Cc
030514	U Ari	709	337	0.58	0.53	370	8.3	6.7	8.1	6.4	Cb
031401	X Cet	1419	590	1.03	1.43	176	5.3	5.5	9.0	2.9	Aa
032043	Y Per	3536	430	1.35	1.63	251	5.7	6.0	8.6	1.7	Ac
II	(Mean)	2009	423	0.87	1.01	309	7.1	7.7	8.8	4.3	Ca
I		1242	336	0.80	0.78	312	6.8	7.9	9.1	5.2	Cb
I, II		1626	380	0.84	0.90	310	7.0	7.8	9.0	4.8	Ca

The plotted mean light curves are shown in Figure 1. The proportion of type A and B curves is distinctly different from those shown in the first discussion, only one star being relegated to type B, while ten are type A. Type C preponderates, as was the case in the previous illustration.

Outstanding features of some of the curves are noted herewith.

S Cassiopeiae, spectral class Se, has the longest period of all, 612 days, and shows a well-marked still-stand on the rise to maximum, usually between magnitudes 13 and 12. It also has a large range in variation, six magnitudes.

RZ Persei also presents a distinct still-stand, but nearer maximum phase. In fact, it almost approaches a secondary maximum and minimum in some individual curves. Other variables which have indications of still-stands are RU and W Andromedae, X Cassiopeiae, and U Persei.

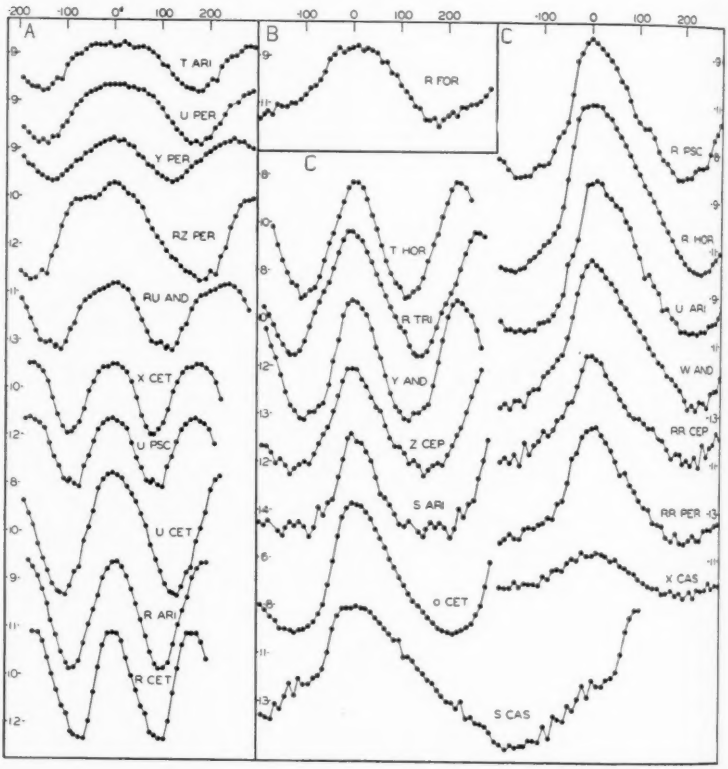


FIGURE 1
LIGHT CURVES OF LONG-PERIOD VARIABLES—II

R Horologii has the largest range in variation of all the variables here discussed, seven magnitudes, and with the exception of *o* Ceti and Y Andromedae, the most rapid rise to maximum. The fastest rate of increase is 2.7 magnitudes in 20 days, or $0^{M}.135$ per day.

The average deviation of the indivdual times of maximum and minimum, referred to the assumed periods, remains about the same as for the first group of stars discussed, seven days for maximum and eight days for minimum. These values indicate a deviation amounting to about 2.4 percent of the period, a value

which can be considered fairly satisfactory when one recalls the vagaries of this type of variable, and the uncertainties involved in deriving the times of these phases.

Jonckheere's Red Star: It would appear that red giants, like white dwarfs, are to come in for their share of attention. Word was received in February from Jonckheere of Marseilles of the discovery of an "étoile rouge remarquable" at $6^h 52^m.5$, $+6° 27'.5$ (1942), magnitude 9, with a request for information as to spectral type. Harvard photographs revealed that the star had a spectrum of Nb type, similar to that of the nearby star, RV Monocerotis. Dearborn and Mount Wilson Observatories had previously listed the spectrum as N and N?, respectively, and Hoffmeister had found, some ten years ago, that the star was variable, between photographic magnitudes 12 and 16, and cited it as either of the Mira or irregular type.

From a recent study of Harvard plates, Dr. Dorrit Hoffleit finds that the star is definitely variable, with a large color index, amounting to four magnitudes. Measures on blue plates show a photographic range in brightness from 13.5 to fainter than 16, and yellow plate observations show the range to be between magnitudes 9.4 and 12, with an indication of a period approximating 500 days, a value not inconsistent with other red variables of Class N.

Light Curve of SS Cygni in 1941: A total of 775 observations of SS Cygni were made by the A.A.V.S.O. in the year 1941, the smallest number reported for many years. However, enough observations were secured to define all the maxima except one, the one which probably occurred in February, when the star was unfavorably placed for observation in this latitude. If, and when, the observations

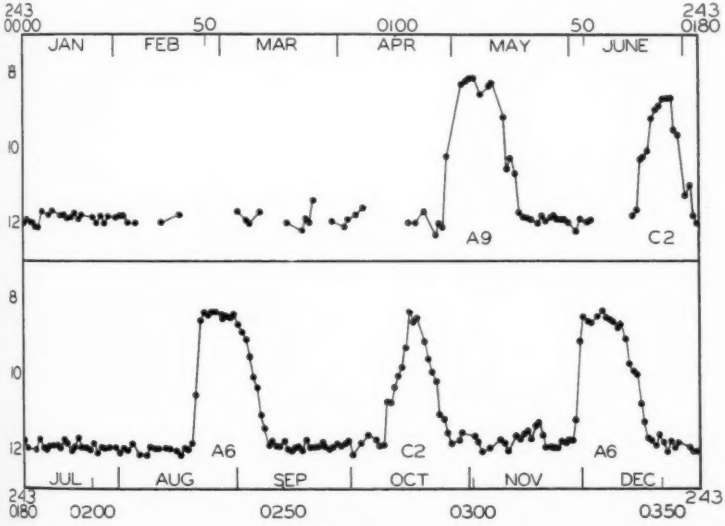


FIGURE 2
SS CYGNI IN 1941

made in Denmark are received, it may be that even that maximum may have been observed. The observations under daily means are listed in Table II, and illustrated in Figure 2.

TABLE II

DAILY MEANS OF SS CYGNI, 1941

243	—0—	—1—	—2—	—3—	—4—	—5—	—6—	—7—	—8—	—9—
0000	2 12.00	2 11.90	1 12.0	1 12.0	1 12.1	1 12.1	1 11.70	.....	1 11.8	1 11.7
0010	.....	1 11.8	1 11.8	1 11.9	3 11.83	3 11.77	1 11.9	1 11.8	.....	.....
0020	2 11.85	1 12.0	1 11.8	1 12.0	2 11.85	.....	2 11.85	1 11.8	1 11.8	1 12.0
0030	.....	1 12.0	.....	.....	.....	.....	.....	.....	1 12.0	.....
0040	.....	.....	.....	1 11.8	.....	.....	.....	.....	.....	.....
0050	.....	.....	.....	.....	.....	.....	.....	.....	1 11.7	.....
0060	1 11.9	1 12.0	.....	.....	1 11.7	.....	.....	.....	.....	.....
0070	.....	1 12.0	.....	.....	.....	1 12.2	1 11.9	1 12.0	1 11.4	.....
0080	.....	.....	.....	2 11.95	.....	.....	1 12.1	2 11.90	.....	1 11.8
0090	.....	1 11.6	.....	.....	.....	.....	.....	.....	.....	.....
0100	.....	.....	.....	1 12.0	.....	1 12.0	.....	1 11.7	.....	.....
0110	1 12.3	1 12.0	1 12.1	2 10.25	.....	.....	.....	2 8.35	5 8.22	1 8.2
0120	1 8.2	.....	1 8.6	.....	2 8.40	1 8.3	.....	.....	1 9.2	1 10.6
0130	3 10.27	2 10.70	5 11.72	6 11.83	3 11.87	3 11.93	.....	1 12.0	2 11.80	4 11.95
0140	2 11.85	1 11.8	2 11.90	1 11.9	1 11.90	1 12.0	.....	1 12.2	1 11.9	.....
0150	2 11.95	1 11.9	.....	.....	.....	.....	.....	.....	.....	.....
0160	.....	.....	1 11.8	5 11.68	4 10.32	5 10.24	7 10.07	5 9.22	1 9.0	7 8.90
0170	6 8.70	10 8.69	5 8.68	4 9.55	2 9.65	3 11.23	2 11.00	2 11.80	1 11.8	1 12.0
0180	2 11.75	3 11.97	.....	.....	1 12.0	1 11.7	2 11.95	1 12.0	2 11.90	5 11.90
0190	3 11.87	8 11.94	1 11.7	1 11.8	4 12.00	3 11.93	8 11.64	4 11.92	2 11.90	2 12.00
0200	2 11.80	2 12.05	6 11.90	3 11.97	4 11.90	1 11.9	4 11.90	3 12.03	5 11.98	3 12.00
0210	1 11.8	.....	1 12.1	.....	2 12.10	2 11.90	2 11.95	6 11.97	.....	4 11.95
0220	5 11.98	.....	4 12.00	1 12.1	8 11.96	5 11.98	3 11.80	8 10.52	7 8.56	2 8.35
0230	9 8.41	5 8.36	2 8.35	6 8.37	7 8.50	8 8.42	6 8.47	1 8.4	3 8.67	3 8.83
0240	2 9.05	1 9.5	2 10.37	3 10.37	7 11.01	2 11.40	7 11.87	4 11.75	2 11.85	9 11.86
0250	8 11.76	4 11.98	5 12.00	7 11.93	7 11.90	3 12.00	3 11.70	7 11.93	6 11.90	12 11.87
0260	6 11.78	2 11.85	4 11.98	2 11.90	6 11.80	5 11.82	1 11.8	4 11.70	1 12.1	.....
0270	1 11.8	.....	1 11.6	.....	2 11.70	2 11.85	6 11.83	1 10.7	4 10.72	7 10.34
0280	6 10.05	3 9.80	2 9.30	3 8.33	5 8.60	2 8.50	.....	9 9.10	3 9.60	4 9.98
0290	7 10.20	6 11.02	5 11.18	5 11.50	1 11.8	.....	2 11.70	2 11.50	.....	.....
0300	1 11.6	2 11.75	1 12.0	.....	3 11.93	.....	.....	1 11.7	2 11.80	1 12.0
0310	.....	3 11.60	4 11.68	5 11.56	6 11.48	6 11.68	6 11.35	5 11.24	3 11.60	4 11.92
0320	8 11.88	2 11.90	1 11.9	4 11.75	3 11.77	3 11.70	4 11.72	5 11.18	3 9.10	2 8.45
0330	1 8.6	1 8.6	.....	3 8.43	2 8.30	4 8.50	4 8.55	4 8.60	3 8.77	5 8.62
0340	2 9.05	1 9.7	2 9.90	1 10.0	6 10.78	2 11.25	9 11.62	5 11.72	3 11.83	4 11.58
0350	7 11.77	1 12.0	2 11.70	2 11.90	3 11.77	.....	.....	1 11.9	1 12.00	2 11.80

Five maxima were definitely observed—two of the "C" type and three of the "A" type. The maximum of December is number 324 of the series observed since 1896.

TABLE III

OBSERVED MAXIMA, 1941

Type	J.D. 10.0 I	Diff.	J.D. Max.	Diff.	J.D. 10.0 D	Diff.
A9	30114	52	30120	51	30130	45
C2	30166	62	30171	62	30175	67
A6	30228	52	30233	51	30242	48
C2	30280	48	30284	49	30290	53
A6	30328	..	30333	..	30343	..

Table III lists the observational data for each observed maximum for these phases. The mean cycle during the year was 53.2 days, as against a mean cycle of 50.4 derived from all the cycles observed from 1896 to 1933.

Observers and Observations: Somewhat delayed, but welcome, observations have been recently received from India and Australia, as well as two excellent contributions from South Africa. How long such reports will continue to come from these distant points is a question, but it is to be hoped observations will continue to be made even if the results can not be made available to us for a long time to come. For the present, at least, we must depend upon our North American observers for the greater part of our current knowledge of the activities of our variables. A few notes on special stars follow.

γ Cassiopeiae is apparently constant at magnitude 2.7. Z Andromedae is again decreasing in light; its magnitude is now about 9.5. Mira, *o* Ceti, is on the rise to maximum, but is now unfortunately too close to the sun for observation. When next available, it will doubtless have passed its maximum, which is due to occur in May. SU Tauri, S Apodis, RY Sagittarii, and R Coronae Borealis are all at normal maximum brightness, but any one of these might suddenly fade away to a minimum. This is especially true of S Apodis, which has not had a minimum in recent years, the lastest having occurred in 1934-35. C. F. Fernald, of Wilton, Maine, found SS Aurigae at maximum late in February. U Geminorum calls for special attention, in order that no maximum may escape us. None has been observed for this star in more than a year. Maximum 325 of SS Cygni proved to be of the narrow A type, and occurred about January 18. If a special watch is not kept on this star just before dawn during the next month it is feared that maxima number 326 and 327 may escape observation.

A listing of the observations received in February follows:

Observations received during February, 1942:

Observer	Var.	Est.	Observer	Var.	Est.
Blunck	16	17	Kelly	13	17
Bouton	34	39	Koons	21	21
Chandra	177	223	Maupomé	120	186
Cilley	75	150	Nadeau	27	42
Cousins	31	74	Parker	20	20
Dafter	11	44	Parks	25	59
Fernald	116	210	Peltier	88	115
Ford	21	28	Petzold	2	2
Griffin	15	15	Rosebrugh	7	22
Harris	8	8	Sill	50	54
Hartmann	137	200	Smith	2	2
Holmes	4	4	Topham	23	23
Holt	161	319	Vohman	9	9
Houghton	23	23	Webb	16	21
Howarth	16	16	Weber	39	39
Jones	16	16	—		—
Kearons	72	138	32	Totals	2156

March 13, 1942.

General Notes

Dr. Joseph A. Pearce, Director of the Dominion Astrophysical Observatory, Victoria, British Columbia, Canada, delivered an illustrated lecture entitled "The Rotation of the Galaxy," on the afternoon of March 2, 1942, at the University of California, Los Angeles. The lecture was given under the auspices of the Department of Astronomy.

Dr. Dinsmore Alter, director of the Griffith Planetarium and Observatory in Los Angeles, has been awarded the honorary degree of Doctor of Science by Monmouth College.

Dr. H. Spencer Jones, Astronomer Royal, delivered the Symons Memorial Lecture of the Royal Meteorological Society on March 18. He spoke on "The Atmosphere of the Planets." (*Nature,* February 21, 1942.)

Camille Flammarion, the French astronomer whose books found readers in all parts of the globe, was born on February 25, 1842, at the small town of Montigny-le-Roi, in Haute-Marne. The son of a shopkeeper, he was educated at a church school and then began work in an engraver's office. His merits being brought to the notice of Leverrier, at the age of sixteen he was given a place in the Paris Observatory where he stayed four years. At the age of twenty he published his first book, "The Plurality of Inhabited Worlds," the forerunner of his "The Marvels of the Heavens," "Popular Astronomy," "The Planet Mars," "Astronomy for Amateurs," and many others. His "Popular Astronomy" when first published in French in 1879 was awarded the Montyon Prize of the Paris Academy of Sciences and was selected for use in the French public libraries. Through an admirer of his writings, Flammarion, in 1883, came into possession of a small chateau and park at Juvisy-sur-Orge and he built an observatory there. The previous year he had founded the review, *L'Astronomie,* and five years after that, in 1887, he started the Société Astronomique de France. His death took place at Juvisy, June 4, 1925, when he had reached the age of eighty-four. (*Nature,* February 21, 1942.)

American Astronomical Society.—The next meeting of the American Astronomical Society will be held at the Yale University Observatory, New Haven, Connecticut, on June 12-14, 1942.

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on Wednesday, March 4, 1942. William E. Stephens, Ph.D., Assistant Professor of Physics, University of Pennsylvania, spoke on "Stellar Atom Smashers."

Jackson-Gwilt Medal and Gift.—At its meeting on 1941 December 12, the Council awarded a Jackson-Gwilt Medal and Gift to R. L. Waterfield, Esq., M.B., B.S., M.R.C.P., "for his general contributions to astronomy, and in particular for his photographic work on eclipses and comets and his visual observations of planets."

The presentation will probaly be made at the Annual General Meeting on 1942 April 10. (*Monthly Notices of the Royal Astronomical Society,* Vol. 101, No. 8.)

Symposium on Spectroscopy

A symposium on spectroscopy will be organized at the University of Chicago under the chairmanship of Professor R. S. Mulliken of the Physics Department. Professor James Franck is organizing a section of discussions in chemistry, while the astronomers of the Yerkes Observatory are contributing a section on astronomical topics. The astronomical sessions are to be held at the University of

Chicago on Monday and Tuesday, June 22 and 23, 1942. Three topics are to be discussed: a) the spectra of comets, b) the spectra of planets, and c) the structure of the earth's atmosphere.

It is expected that Dr. Andrew McKellar will come from Victoria to participate in the discussion of the first topic, together with Dr. P. Swings of Yerkes and Dr. N. T. Bobrovnikoff of the Perkins Observatory. The speakers on the other topics have not been definitely chosen but it is expected that Dr. Oliver R. Wulf will preside during the session on the structure of the atmosphere, with Dr. Fred Whipple of Harvard University and Dr. C. T. Elvey of McDonald as the principal speakers.

Everyone interested in these topics is, of course, cordially invited to attend the meetings and to participate in the discussions.

O. STRUVE.

A Rapidly Moving Object.—The Harvard College Observatory *Announcement Card* No. 619 conveys the following information. "A radiogram received last night from Professor Lundmark of Lund, Sweden, transmits a message from Professor Strömgren of Copenhagen, reporting that Dr. Y. Väisälä of Tartu, Finland, has observed a 'fast moving object' of the thirteenth magnitude, stellar in appearance. The following positions are given:

1942 U.T.	R.A. h m	Dec. ° ′
March 12.01771	10 56.1	−0 23
13.77424	11 1.3	+3 25

HARLOW SHAPLEY."

March 17, 1942.

Notice

The Science—Technology group of the national Special Libraries Association has undertaken to compile, for the benefit of the users of the Russian scientific and technical periodicals, current or otherwise, a complete list of the holdings of such periodicals in all the libraries of the United States and Canada, as far as possible, whether personal, institutional or industrial. Owners and librarians in charge of such materials are asked to coöperate by sending a detailed statement of their holdings to Miss Nathalie D. Frank, 512 West 162nd Street, New York City. Please state also whether the journals can be borrowed on inter-library loan and whether the library has facilities for photostatting or microfilming.

Summer Courses in Astronomy at Harvard

This summer Harvard University will not hold its special Graduate Summer Conferences in Astronomy and Astrophysics. Instead there will be offered a complete program of courses in Astronomy as part of the regular University program, which, since the declaration of war in December, is being run on a twelve months continuous schedule.

The summer session at Harvard will be divided in two six-weeks periods, one running from June 29 to August 8, the other from August 10 to September 18. During each of these periods special courses will be offered, some of which may be of interest to astronomers elsewhere, especially to those who are contemplating special war research or the teaching of war courses.

During the first period Mr. James G. Baker will give a course: "General Problems of Optical Systems." It will cover the theory and design of optical

systems, lenses, mirrors, and combinations, and is intended primarily as a course for those desiring to engage in optical construction for governmental needs and for teachers of practical optics.

During the second period Dr. George Z. Dimitroff will offer a course in photography with special stress upon the photographic problems of importance in war activities, such as the properties of various types of emulsions, the techniques of processing and printing, and the methods of photometry. Also, during the second period, Dr. Donald H. Menzel will give a course on theoretical physics and astrophysics in which the subject matter will be chosen with the aim of preparing advanced physics students for war research.

The regular undergraduate course in descriptive astronomy, adjusted in accordance with the recommendations of Dr. C. C. Wylie's committee (see *Pop. Ast.*, **50**, 171, 1942), will be given during the first period by Dr. Bart J. Bok. Dr. Fred L. Whipple will be in charge of two undergraduate courses in navigation, one to be given in the morning as part as the University program, the other an extracurricular evening course. Dr. Whipple's courses fall in the first period. If there is sufficient demand, Dr. Whipple offers to give some seminars on the teaching of navigation for staff members at the Observatory and for special visitors.

Since it is possible that some astronomers may wish to attend the courses of Baker, Dimitroff, Menzel, or Whipple, arrangements are being made for a series of twelve colloquia on Tuesday evenings at 8:00 P.M. All astronomers who happen to be within easy reach of Boston, for reasons relating to the war or otherwise, are cordially invited to participate in these weekly sessions. Please address all inquiries to Harvard Observatory, Cambridge, Massachusetts.

The Observer.—Copies of Volume 3, Nos. 1, 2, and 3, of the above named publication have recently been received at this office. It is the official publication of the Yakima Amateur Astronomers, Yakima, Washington. The regularity of publication and the material published indicate that the activities of the organization are kept alive and the interest of the members is stimulated through this publication.

El Universo.—This is the very appropriate name of an astronomical Journal recently begun in Mexico. It is in the Spanish language and is to be the official organ of the Astronomical Society of Mexico. It apparently is to appear bimonthly, as Number 1 is dated November, 1941, and Number 2, January-February, 1942. The papers published so far are popular in character, evidently intended for the general reader. The need of such a magazine was felt doubtless because of the stimulation of interest in astronomy as a result of the recent dedication of the Tonanzintla Observatory, in which many astronomers from the United States and Canada took part.

The purpose of this new journal would seem to be quite analogous to that of this magazine. POPULAR ASTRONOMY, therefore, wishes in its fiftieth volume to express a hearty welcome to *El Universo* upon its entry into this field of publication, and to express its felicitations and heartiest good wishes for a most successful career.

C. H. GINGRICH, *Editor.*